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STUDY OF SINGLE-RESPONSIBILITY CONCEPTS FOR WATER POLLUTION CONTROL PROJECTS

BECHTEL, INCORPORATED

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

APRIL 1974

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Characteristics of various types of construction projects are summarized. Method and time of contractor selection, level of contractor responsibility, degree of project control, potential for schedule compression, firmness of cost estimate, availability of process guarantee, and typical compensation methods are described for each project type. Advantages and disadvantages of each type are discussed.

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STUDY OF SINGLE-RESPONSIBILITY CONCEPTS FOR WATER POLLUTION CONTROL PROJECTS

Prepared for

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY

Final Report

BECHTEL INCORPORATED

April 1974

FOREWORD

In accordance with the Environmental Protection Agency (EPA) Delivery Order 68-01-1364 (dated May 21, 1973) of Contract 68-01-0973 to Bechtel Incorporated (dated November 17, 1972), Bechtel has performed a Study of Single-Responsibility Concepts for Water Pollution Control Projects.

This study was performed for the U.S. Environmental Protection Agency, Municipal Wastewater Systems Division, Mr. Harold Cahill, Director, by Bechtel Incorporated, Hydro and Community Facilities Division, Mr. Richard P. Godwin, Vice President and Deputy Division Manager, and Mr. William A. Sandberg, Project Manager.

Acknowledgment is given to the members of the Bechtel Advisory Panel – Dr. E. J. Cleary of the University of Cincinnati, Mr. J. F. Lagnese of Duncan, Lagnese, and Associates, Inc., and Dr. D. A. Okun of the University of North Carolina – who were kind enough to review and comment upon the report drafts, but are not responsible for the contents of the report as issued.

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Section 1

INTRODUCTION

1.1 SCOPE OF REPORT

The objective of this report is to describe various means of controlled accomplishment of design & construct* projects that comprise planning, engineering design, construction, start-up, and initial operation of a water pollution control facility for a public owner. In this report, the forms of organization and contract provisions considered are those that contractually centralize responsibility for the satisfactory design and construction of wastewater treatment facilities. It is expected that the methods described here will be put into practice by 1) a public owner who lacks the engineering, construction, and other staff personnel needed to accomplish the project without outside help and who does not wish to temporarily employ such talent, and 2) a large public owner who may choose to contract for outside assistance to increase his capability to carry on capital projects.

The report discusses methods used by both public and private owners for contracted design and construction of process facilities. The examination of the methods of the private sector has been made with the intention of pointing out techniques that might be applicable to work in the public sector.

To simplify discussion of the many variations of organizational arrangement, contract terms, payment provisions, obligations, and interrelationships between the parties involved in major capital projects, this report

*Editor's Note: The term "design & construct," as used in this report, is substituted for the term "design/construct," as it appears in EPA regulations. This has been done to avoid ambiguity due to the use of the slant (/) in a conjunctive, instead of its normal alternative, sense.

deals with four basic organizational forms plus the traditional form of performing public works project. In addition, a special case that is a combination of two of the basic forms is briefly discussed.

It should be noted at the outset that the concept of centralized (or single) responsibility for design & construct projects, as presented in this report, is considerably broader than that exemplified by the project approach known as "turnkey." Turnkey is included here as only one possible combination of procedural options available within one of the four basic forms of design & construct project organization.

The closing section of this report discusses the possibilities of improving the performance of both the project and the resulting treatment facility through the use of the forms of organization and contractual relationships presented in the body of the report. A glossary of terms used in this report is included in Appendix A.

1.2 ORGANIZATION OF STUDY

The study which produced this report was undertaken in two phases: Phase I, which resulted in Sections 1, and 3 through 8, was a review of present design & construct practices and experience in both the public and private sectors. Phase II, which resulted in Section 9, was an analysis of the alternative design & construct methods of project execution as related to EPA objectives. Section 2 is a summary of the whole report.

1.3 BACKGROUND FOR STUDY

Under EPA Regulation 40 CFR Part 35, as previously issued, the construction of wastewater treatment facilities receiving federal financial assistance authorized in Section 8 of the Federal Water Pollution Control Act could proceed only after final plans and specifications had been approved by the EPA Administrator. In addition, construction work had

to be performed under the lump-sum or unit price compensation method, and competitive bidding was necessary prior to award of the construction contract. However, the regulations placed no requirements on the applicant as to the contents of the contracts for the project. Under these regulations, the applicant for federal financial assistance would normally use separate contracts for design and construction of the facility in accordance with his conventional practices and procedures.

On February 28, 1973, revised regulations were published in the Federal Register amending the then-existing regulations and adding provisions to permit combined design & construct contracts. A design & construct contract was defined in the new regulations as a combined agreement covering engineering design and construction whereby the bidder submitting the lowest responsive lump-sum or unit price bid, based on performance specifications prepared by the applicant, would be selected to perform the work. Under this contract, the design & construct contractor would be required to provide adequate guarantees of process performance of the completed facilities. (These regulations were further revised on February 11, 1974, but the ideas expressed above remain basically unchanged.)

Although this regulation revision (which has been popularly characterized as the turnkey regulation) is presumable intended to allow the grantee more options in project execution, it has been interpreted by some as representing EPA's intent to specify the turnkey method. And, in fact, it was not clear in the absence of implementing guidelines, whether these new regulations would have permitted the use of forms of combined design & construct project forms other than turnkey that might have been of equal or superior utility. However, it is felt that other options must be considered if the EPA is to realize its objective to provide public agencies with effective alternative project methods. Expected gains from new methods are: 1) the creation of incentives for design innovations, evaluation of alternatives, improved cost-effectiveness, and new technology;

2) the achievement of overall time savings; 3) the assurance of greater responsibility on the part of the process designer for facility performance.

This study is based on the premise that the significant element in the EPA intention is not the turnkey approach per se, but rather singleness of responsibility; that it is essential that the grantee and the EPA look to a single qualified organization to be responsible for determining what is needed, for designing and building the facility, and for putting it into successful operation, all within agreed-upon schedule and cost estimate. Based on this premise, the report is intended to provide information for use by the EPA when developing regulation revisions and the implementing guidelines for contracting methods specifically suited to public agency wastewater projects. It is recognized, however, that in some localities many of the possibilities discussed in the study may be only of academic interest because of local external conditions (e.g., aesthetic, environmental, safety, and land use control procedures; long-established business and market practices; state regulatory requirements; and political factors) none of which may be directly influenced by EPA regulation.

1.4 TERMINOLOGY

The terms used in this report are intended to be those in common use in the engineering and construction professions, but it is recognized that the understanding of terms may vary widely. In an effort to avoid ambiguity, a number of terms are defined in a glossary, Appendix A. When a defined term is introduced for the first time in Subsection 3.2, it is written in capital letters. No attempt, however, is made to define all of the terms used in this study, and any undefined terms should be considered in their context and be assumed to have their commonly accepted meanings.

Section 2

EXECUTIVE SUMMARY

In recent years, the EPA has sought to extend and improve the options available to recipients of federal water pollution control grants for contracting project engineering and construction. It has been felt that the public interest may be well served by allowing, under appropriate circumstances and controls, organizational practices that may represent a departure from those traditional for wastewater projects. These practices include some methods used in other public works fields. In addition, an attempt is being made to apply private sector experience to public sector projects. The improvements sought include earlier use of facilities, lower costs, better performance, and increased application of new technology. Since in the proposal for this study, it was suggested that these goals could best be achieved by centralization of responsibility for project execution in a single contracting party, this report describes the various methods for providing single-responsibility leadership of "design & construct" projects and discusses the conditions under which each method is applicable.

2.1 PROJECT FORMS

Design & construct project can be carried out in a number of different organizational forms. These potentially involve four principal parties: the owner, the engineer, the constructor or the engineer-constructor (considered as one party), and the project manager (in conjunction with whom the owner may elect to award contracts for engineering, construction, and other services to be administered by the manager).

In a single-responsibility project, the owner assigns to a single contractor the non-policy portion of the owner's project functions. The project organizational forms available to the owner are determined by the contractual relationship between the owner and each of the various parties responsible for carrying out the work. The form selected, and therefore the contractual relationship entered into, is determined by the owner's need for project control, process performance guarantees, outside technical assistance, cost control, and schedule requirements. And throughout this entire procedure, everything must be considered in the context of legislative and institutional restraints on the owner, regarding such matters as contractor selector methods, compensation method for each portion of the project, and review and approval requirements.

The possible combinations of relationships between the owner, engineer, constructor, engineer-constructor, and project manager result in four organizational forms for contracting single-responsibility projects. In each of these forms, the duties of the responsible contractor are contained in the title. The four forms are:

- Engineering & Construction (EPC)
- Project Management (PM)
- Engineering & Management (EM)
- Construction & Management (C&M)

Also included for consideration is the traditional two-party form in which engineering and construction is contracted separately:

- Engineering : Construction (E:C)

These forms are illustrated diagrammatically in Figure 2-1 and discussed below. (For a more detailed presentation of this material, see Figure 3-1.)

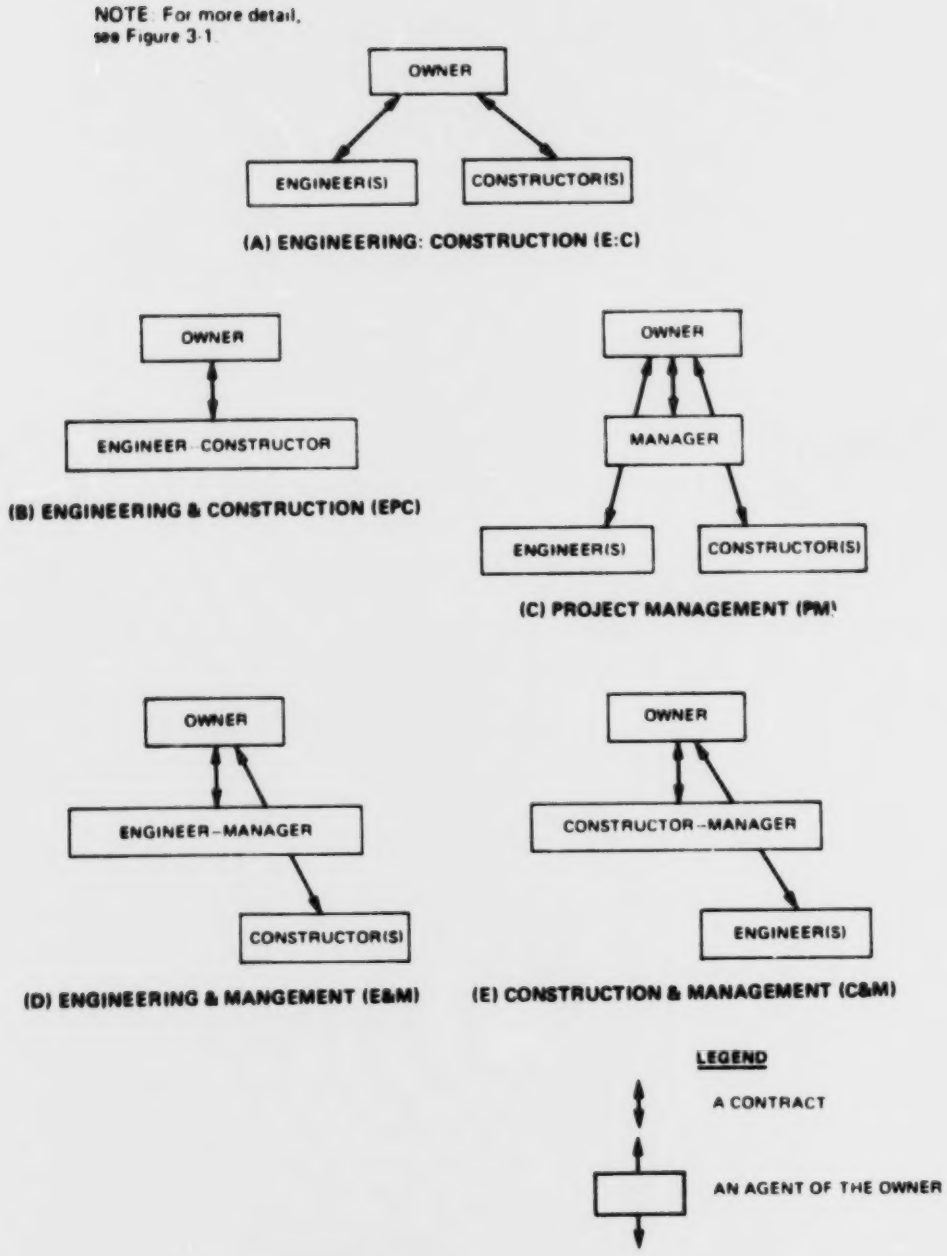

Figure 2-1. Pictorial Representation of Project Forms

Engineering : Construction (E:C) – Traditional

The traditional method of contracting public works is to use a professional engineer for the design and a general contractor for construction of facilities. This method of organization is called the two-party, or the engineering : construction (E:C) form. Since with E:C, the owner must retain the overall coordination responsibility, it cannot be considered a single-responsibility form as defined in this report. But because under such a form, the engineer is often expected to assume more responsibility for the project than simply the engineering, E:C takes on some of the characteristics of the E&M form.

Engineering & Construction (EPC)

With the engineering & construction (EPC) form, the owner contracts with a single firm (or joint venture) to carry out both the design and the construction – and frequently the procurement (P) – for the total project. The single firm or joint venture so contracted is known as the engineer-constructor.

Project Management (PM)

The organizational arrangement in which a fourth party is contracted to manage the project is defined as the project management (PM) form. Here, the owner contracts individually with the manager, the engineer(s), and the constructor(s). The manager acts as the owner's agent in dealings with the engineers and constructors and accepts overall responsibility for the project.

Engineering & Management (E&M)

A variation of the PM form is the engineering and management (E&M) form. Here, instead of contracting with a fourth-party manager, the owner retains the engineer to be responsible for the management of the

project, including construction, as well as for the engineering. The E&M organization resembles the E:C form to some extent but calls for considerably more managerial and construction know-how on the part of the engineer than is required for E:C.

Construction & Management (C&M)

Construction and management (C&M) is another variation of the PM organization and is similar to the E&M form in that no fourth-party manager is retained. In C&M, the owner assigns to the constructor both the overall responsibility for the management of the project and the construction responsibilities. The C&M form is uncommon in current practice.

The foregoing organizational forms have much in common. And many variations and combinations of these four basic forms are possible. In one such combination of special interest (symbolized PM : EPC), the manager is retained to oversee one or more engineer-constructor(s) performing EPC projects. This organizational form is useful to an owner involved in a project that taxes his capability to supervise an EPC contractor without outside assistance.

The organizational forms presented above are further defined in Section 3 and are individually discussed in Sections 4 through 8. Table 2-1 very generally summarizes and compares the chief characteristics of the several forms.

Discussion of Forms

The single-responsibility concept provides the owner with the following benefits:

- Good overall project performance as a result of continuing project leadership by a fully qualified owner's representative

- Tighter process and performance guarantees
- Closer control of costs and schedule
- Shorter project schedules through the paralleling of more project activities
- Integration of construction planning into the design phase

While the basic organizational structures are easy to describe, the variety of acceptable variations is very great and cannot possibly be adequately described in a synopsis such as this.

The EPC contract maximizes the number of activities placed under the responsibility of a single contractor. The degree of contractor involvement makes it difficult for the owner to exercise control over the project. At the other extreme is the PM form, in which the project manager has no direct design or construction performance responsibility. In this case, the manager is the owner's control medium, but because the manager must work through the owner's contractors, he is not in a position to assume as significant a contractual responsibility as the EPC contractor might be able to.

Guarantees are generally spoken of in terms of the financial redress available to the owner (that is, the extent of financial liability accepted by the contractor) and are a function of the extent of the contractor's direct performance of the work and the amount of compensation he receives. When the various project forms are compared, it is evident that the contractor does the least amount of work and receives the least amount of compensation in projects of the PM types, whereas the reverse holds true for EPC type projects.

If maximizing the responsibility of the contractor to furnish guarantees and provide for financial recovery in the event of failure were the owner's

Table 2-1

CHARACTERISTICS OF PROJECT FORMS

CHARACTERISTICS	PROJECT FORM				
	TWO – PARTY	SINGLE RESPONSIBILITY			
	E:C	EPC	PM	E & M	C & M
Responsible Contractor	(Owner)	Engineer-Constructor	Manager	Engineer-Manager	Constructor-Manager
Responsibility of Contractor(s) to Owner for:					
Overall Project	None	High	High	High	High
Schedule and Cost	None	High	Moderate	Moderate	Moderate
Process Performance	Low	High	Moderate	High	Moderate
Potential for Process Guarantee	Low	High	Moderate	High	Moderate
Relative Degree of Control:					
Schedule	Moderate	Low	High	Moderate	High
Cost	Low	Low	Moderate	Moderate	Moderate
Work Quality	High	Low	High	High	Moderate
Likely Time of Selection:					
Engineer	Pre-Planning or Pre-Design	Pre-Design	Pre-Planning or Pre-Design	Pre-Planning	Pre-Planning
Constructor	Pre-Construction	With Engineer	Pre-Construction	Pre-Construction	Pre-Design
Manager	None	None	Pre-Planning or Pre-Design	With Engineer	With Constructor
Typical Compensation Basis:					
Engineer	Negotiated – Reimbursable Cost	Competitive –	Negotiated – Fixed Price	Negotiated – Percentage Price	Negotiated – Fixed Price
Constructor	Competitive Bid – Fixed Price	Phased Negotiation – Fixed (or Target) Price	Competitive Bid – Fixed Price	Competitive Bid – Fixed Price	Negotiated – Reimbursable with Fixed Fee
Manager	None	None	Negotiated – Percentage Price	With Engineer	With Constructor
Experience with Form:					
Public	High	Low	Moderate	Moderate	None
Private	Moderate	High	High	Moderate	Little
Potential for Schedule Compression:	Low	High	Moderate	Moderate	High
Firmness of Facility Cost at Constructor Award:	High	Moderate	High	High	Low

only consideration, the EPC contract would always be the one of choice. In actual practice, however, a compromise has to be struck between contractor responsibility and owner control.

In those project forms (such as EPC) in which the contractor has a major direct-performance obligation (and especially if he is working for a fixed compensation), his primary interest is to conduct work in the most efficient and profitable fashion within the limitations of the project specifications. Moreover, because engineering and construction decisions are made wholly within the same contractor's organization, he is encouraged to take unilateral action in project decisions, such as the economics of materials selection and construction practices. This reduces the owner's involvement in control of the decision-making processes. As the project develops, the owner may find that a kind of adversary relationship develops between himself and his contractor.

On the other hand, in the PM form, the manager does not directly perform any engineering or construction services, but assumes the responsibility, on behalf of the owner, for the work performed by each contractor. The manager thus represents the owner's interest in dealing with the performing contractors on an equal-capability basis, and the probability that the project is carried out properly is maximized.

The tradeoff is therefore between (1) a project form (such as PM) in which the owner's interest in well represented, but which does not provide firm guarantee provisions to compensate the owner in the event of process performance failure, versus (2) a form (such as EPC) in which the contractor has total financial responsibility for his work, but in which the owner gives up a portion of his ability to control the ongoing project activity.

In many cases, the owner may find it advantageous to choose an organization form somewhere between PM and EPC. By so doing, he may be able

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to achieve a suitable balance between contractor guarantees and owner control within the context of prevailing laws, regulations, and procurement rules.

The owner can vary the form of the project in a way that depends on the extent of the various functions assigned to each of his contractors. It can be demonstrated that a path of evolution exists from one to another of the basic forms described here. Figure 2-2 provides a pictorial representation of the interrelationships between the forms and their characteristics. (Some precision of illustration is lost by using a sphere.)

In this figure, the four project forms defined in this report are located around the equator. The E:C form is at one pole; the consolidated PM:EPC variation is at the other pole.

As one moves from the EPC form to the PM form, there is a tradeoff of guarantees for control as illustrated on the guarantees/control axis. The relationship of the guarantees/control axis to the other two axes suggests that as one moves along the equator, the singleness of responsibility remains approximately* constant, while the degree of project control, the strengths of guarantees, and the balance between engineer and constructor control all change. For example, the C&M and E&M forms differ primarily in the seat of responsibility; the former invests full responsibility with the constructor while the latter invests full responsibility with the engineer. This relatively simple difference, however, produces a profound effect on the types of procedures used to implement these two forms.

Figure 2-2 can be useful for determining in gross terms the characteristics of project forms that are combinations of the six forms depicted here. By projecting from the position of a combination project form on

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* Recall that the spherical model is only an approximation.

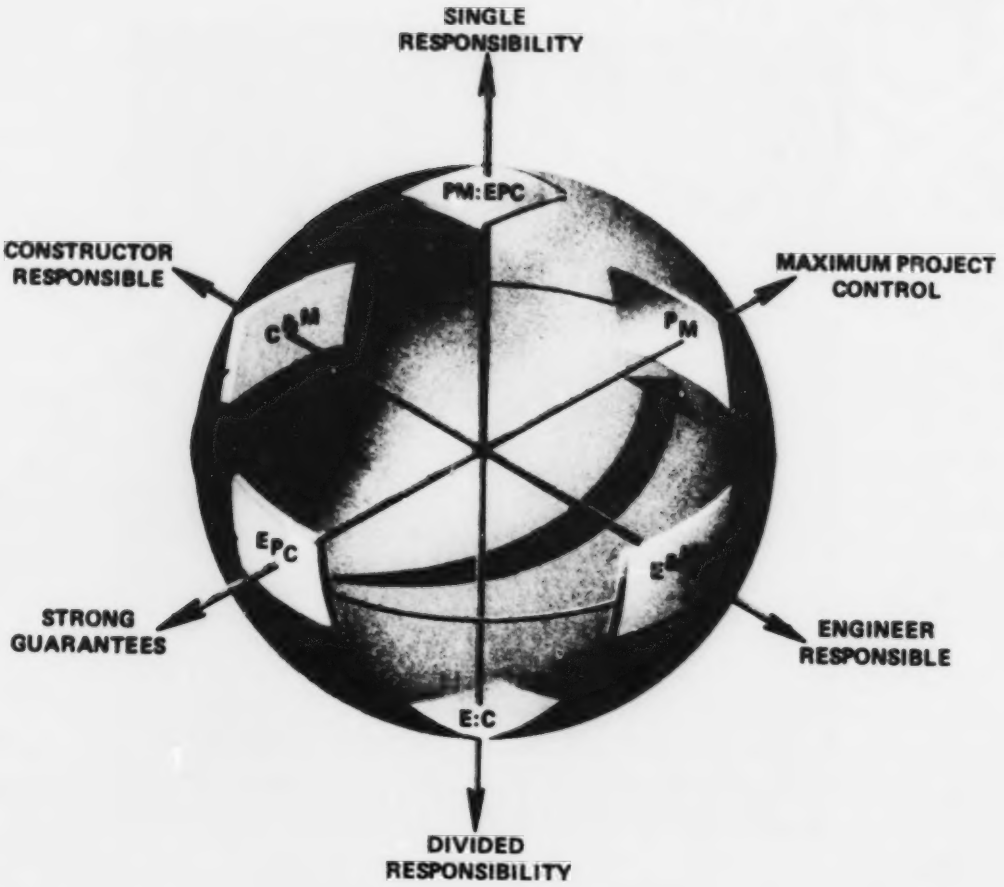


Figure 2-2. Pictorial Representation of the Interrelationships Between Project Forms

the surface of the sphere onto the various axes, one can make a rough analysis of the characteristics of this form. For example, if the owner were to engage several EPC contractors instead of one to perform the work, this project form would appear at a point intermediate between EPC and E:C in the lower, front portion of the sphere, indicating that there is a reduction in the singleness of responsibility and in the strength of the guarantees. If, however, the owner were to place a project manager over the several EPC contractors, this project form would fall at the point intermediate between PM and PM:EPC (which is very highly centralized and therefore at the extreme end of the single-responsibility axis). Another example is a project procedure, frequently used in public works projects, that involves an engineer, plus a construction manager overseeing the procurement-construction activities. This might be symbolized as an E:CM or E:M and would be located intermediate between the E:C and the PM on the lower, rear portion of the sphere, indicating some division of responsibility, a weak guarantee position, and a moderate degree of control.

2.2 CONTRACTOR SELECTION

The single-responsibility concept calls for early selection of the contractor who will have overall responsibility for the project, so that continuity can be provided from initial design decisions through operation and acceptance. This is a rather straightforward matter for the E&M form because the engineer is immediately involved with the planning and design phases of a given project. Similarly, in the EPC form, the contractor, by definition, does design work and at least some of the planning as well. In the PM form, the manager should be selected before or when the engineer is retained for the design work. In the C&M form, it is necessary to select the constructor for the management role at the beginning of the design phase in order for it to be a single-responsibility form.

Since the methods for selecting the types of contractors in the private sector are much less restrictive than in the public sector, the transfer of practices from one sector to the other is difficult. Most public works procurement rules differentiate markedly between the selection of a "professional" contractor (i.e., the engineer and the manager) and the selection of the "nonprofessional" contractor (i.e., the constructor and equipment suppliers). The former is usually selected by negotiation, the latter by price-competitive bidding among qualified candidates. The result is that the E:C, E&M, and PM forms can be entered into prior to detailed definition of the physical facilities, whereas special arrangements are needed to enter into the EPC or C&M forms in the very early phases of the project.

It is possible, however, to select the engineer-constructor (EPC) on a firm-price basis using only basic process design criteria in a manner often practiced in the private sector. During the bid preparation period, the engineer-constructor performs a portion of the design and solicits pricing of major equipment to an extent suitable for the support of a definitive estimate and the resulting bid price.

However, very large and/or complex projects cannot be bid firmly in the above manner. For to hold to this form, it would be necessary to retain the EPC contractor on a professional basis to perform the engineering needed for the preparation of the process design criteria. Modification of procurement rules generally would be required to allow such an early selection of the engineer-constructor (EPC) or the constructor-manager (C&M) as would be required to assure a full single-responsibility approach. The method then used would be to select the contractor on the basis of his qualifications and to contract for a later development of a firm price for his services when these are adequately defined. To satisfy public concern in the absence of price competition, the owner at the appropriate times could retain a consultant who would serve as referee

for review of the contractor's estimate(s) and would assure that the basis for compensation was appropriate.

In any event, public sector procurement and contractor selection methods are in need of change to allow the maximum flexibility in the selection of project methods.

2.3 COMPENSATION

A major issue in construction contracts is the type of compensation. There are two basic types of compensation for professional or nonprofessional services and materials: fixed price, and reimbursable cost. Within these two categories, many variations exist. These include lump-sum, percentage (of facility) cost, cost-plus, unit price, and fixed quantity. Each of these types can be modified by the application of a guaranteed maximum price, target price, various incentive formulas, and variation in the number of stages and time of development of the compensation basis.

As a rule, all the project forms can be employed with fixed-price compensation for the constructors. Exceptions are C&M, and in some cases EPC, which require that the constructor's compensation be on an initial reimbursable basis, subject to firmer definition in a later phase of the project.

Several project-related factors influence the choice of compensation method acceptable to both owner and contractor. They include the size of the project, the extent of commercial risk involved, the thoroughness of the definition of the scope, and the procurement rules that are applicable.

2.4 RESPONSIBILITIES, GUARANTEES, AND LIABILITIES

The responsibilities of the various contractors are established in the contract. The amount of responsibility a contractor assumes depends on such factors as activities performed, the risks or other factors beyond his control, and the amount of profitable compensation for each activity. For a

single-responsibility project to be effective or to offer any advantages, certain guarantees must be stated in the responsible contractor's contract and are usually stated in the other contracts as well. These guarantee forms may include:

- Performance
- Materials and workmanship
- Completion date
- Process

The performance guarantee is concerned with the assurance of completion of the project and is frequently supported by a performance bond. Related to the performance guarantee is the materials and workmanship guarantee, whereby the contractor pledges to install quality materials in a workmanlike fashion. The materials and workmanship guarantee, together with the performance guarantee, may be supported by holdback of compensation until facilities are accepted by the owner.

In the completion date guarantee, the contractor promises to finish his work by a specified date. This date may be stated in the contract without additional provision, but usually exists as the basis for a bonus/penalty provision.

One of the advantages of a single-responsibility contract is the process guarantee. The process guarantee affirms the ability of the completed facility to perform its functions satisfactorily. Process guarantees are somewhat rare in the public sector, except for certain types of U.S. government building contracts, and are used only occasionally in the private sector because of the additional cost involved and the difficulties of adequate definition and measurement.

When the appropriate contractor selection methods and compensation methods are used, the single-responsibility contract in design & construct

projects provides greater assurance of satisfactory design, construction and operation than traditional methods. However, written guarantees are not free of charge. As the contractor's risk is increased, his requirement for compensation also increases. Contractors customarily limit their liabilities to a predetermined amount, primarily to protect themselves from being forced out of business in the event of extremely high cost overruns. The limit is generally defined as some fraction of the total compensation to be received.

2.5 REGULATIONS

The selection of project forms is usually subject to federal, state, and local laws and governing regulations. These may be quite extensive and do vary markedly from one section of the country to another, as well as from one type of owner agency to another. Many laws and regulations have been enacted that limit the latitude of the public owner in the selection and compensation of his contractors. In the private sector, the owner and contractor usually have wide latitude under applicable contract law and commercial codes.

In addition, certain federal requirements are applicable to recipients of grant funds, and especially to wastewater management facility grants. These include the current regulations of OMB Circular A102 and the EPA regulations under Title 40, Part 35, published February 11, 1974. Circular A102 requires that construction labor, materials, and equipment be procured by competitive sealed bids; that award of construction should be made to the lowest responsive, responsible bidder; and that proprietary, exclusionary, or discriminatory requirements must be absent from the specifications. Some of the successes of private sector project performance may be attributed to the owner's ability to negotiate construction contracts and to direct procurement in an advantageous manner.

EPA regulations provide for grants for the performance of Step One of a project (the preparation of facilities plans and related studies – or the planning phase); Step Two of the project (the preparation of construction drawings and specifications – or the design phase); and/or Step Three (the fabrication and building of a treatment works – or the construction phase).

Application for grants for each of the three steps is consistent with traditional practice. The most recent regulations, however, provide for a grant combining Step Two and Step Three. This allows the owner to proceed with a project form that combines both design and construction.

2.6 DISCUSSION

Some fundamental characteristics of public works projects that differentiate them from private sector projects are:

- The absence of the profit motive on the part of the owner
- The stewardship responsibility of public officials handling public funds
- The need for full public disclosure of business matters and decision variables in public agency procedures (e.g., aesthetics, land use, safety, rate structures, financing, intervenor, participation, and fair employment practices)
- The relative absence of constructor preselection
- The legal and regulatory obligation to select the lowest responsible bidder for construction work
- The limited technical capability of owners
- The uniqueness of major projects, or the infrequency of their occurrence during the tenure of public officials

The transfer of private sector methods to public works projects must take into account the differences listed above.

There is a current trend in public works undertakings to adopt and implement new, improved project procedures. And now may be the time to seek a thorough review and revision of public procurement and contractor selection methods.

The EPA objectives sought through single-responsibility design & construct project methods are:

- The shortening of project schedules
- The improvement of processing performance of treatment facilities
- The encouragement of new technology

Implicit in the above is the desire to increase the cost effectiveness of water pollution control expenditures.

Accelerated project techniques allow schedules to be shortened in all the project forms discussed in this report. These techniques reduce the time between the completion of the design and the start of construction and permit increased preprocurement of material. The greatest promise for schedule acceleration, amounting to as much as 20 to 25 percent, is offered by EPC and C&M. The application of these accelerated methods has been impeded by existing procurement rules, extensive agency review requirements at all levels, and institutional traditional practices.

Improved process performance is frequently equated with tight process guarantees. Such guarantees, however, are difficult to define and their validation is difficult to quantify. As a consequence, such guarantees must necessarily have limited financial support — probably amounting to less than five percent of the facility cost. (It has been suggested that greater process satisfaction will result simply through the application of the single-responsibility concept of design & construct project methods.)

Both the shortening of project schedules and the improvement of processing performance of treatment facilities cannot be readily achieved if governmental review agencies make changes in design criteria or details during the course of the project.

None of the project forms appears to offer any advantage in stimulating new technology beyond that which exists in normal engineering activity. The invention and development of new equipment and processes will be mainly the task of the academic community or the proprietary process or equipment suppliers, and will appear in projects as these ideas are tested and made commercially available.

Given the relaxation of existing external factors inhibiting change, the project form best suited to any given project will vary and will be a function of:

- The size of the project
- The complexity of the technical or managerial aspects of the project
- The size and sophistication of the owner's staff
- The availability of competent single-responsibility contractors
- The availability of a complete performance criteria package

The best project form is probably that which encourages the selection of the most qualified assemblage of contractors.

It may be concluded that two of the EPA objectives – shorter schedules, improved process performance (and the inherent cost savings resulting therefrom) – can be approached through a broadening of the options available to grantees which would allow them to apply single-responsibility design & construct project forms. Because of the myriad restraints beyond the direct control of EPA, these options should be facilitated by permissive, rather than directive, regulations and guidelines.

Section 3

BASIC CONSIDERATIONS

3.1 INTRODUCTION

When an owner is faced with the need for the construction of new or expanded wastewater treatment facilities within his jurisdiction, he has a number of decisions to make. These decisions pertain to obligations relating to the required quality of effluent, the time needed for completion of the facility, the available methods of financing, and the extent of participation of cognizant public agencies. If state and federal agencies specify the require effluent quality, this specification becomes the basis for determining the treatment method and hence the type of physical plant and its associated cost. The completion date requirement may be self-imposed and based on population, flow, and loading projections prepared by the owner, or it may be mandated by a pollution control authority. Financing decisions are influenced by the probable cost of the plant and the availability of grant funds from the state and federal governments. It is important to make an accurate cost prediction at the earliest possible date and to maintain good cost control throughout the project. All of these considerations must be dealt with within the context of the owner's enabling legislation and procedural rules.

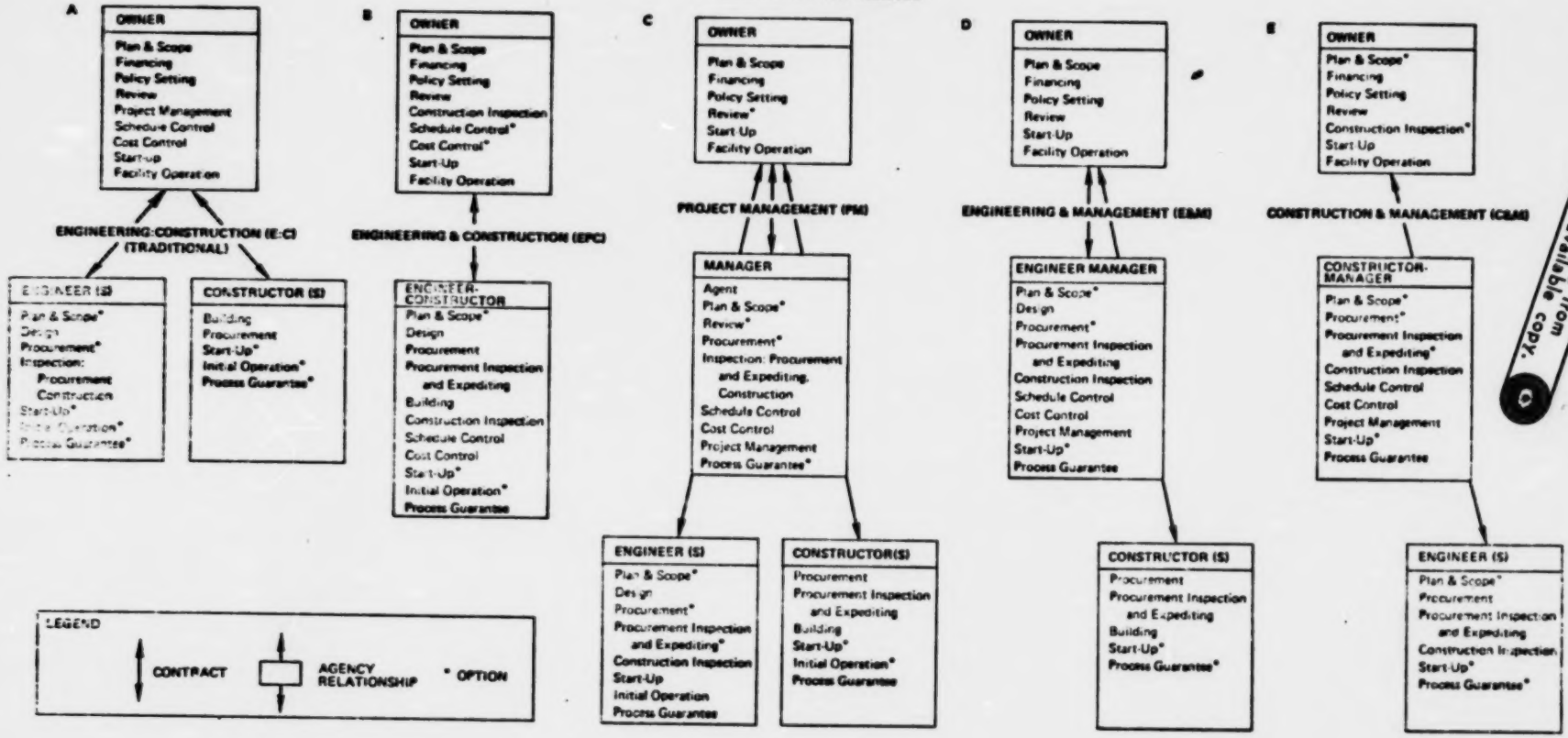
Traditionally, wastewater treatment plants have been designed and built in a two-step procedure: 1) a professional engineering consultant is retained to do the planning and design services, culminating in a design report which serves as a bid package for the solicitation of lump-sum, competitive bids

for the construction of the facility: 2) the facility is constructed in accordance with the engineer's drawings and specifications. In other types of public works projects and to a major extent in the private sector, combined design & construct methods of approach to capital projects are practiced in which the same contractor is responsible for both the design and the construction of the facility. It was in this context that the U.S. EPA revised its construction grant regulations to allow a grantee to apply other methods of approach to the performance of capital projects associated with the wastewater quality improvement programs.

When considering which procedure to adopt, the owner must be aware of the characteristics of each of the procedures, he must know what is commercially available to him from contractors, and he must be cognizant of his own capabilities.

This report deals with essentially four basic organizational forms for the performance of design & construct single-responsibility projects and discusses in detail the characteristics of each. An attempt was made to differentiate between the nature of each organizational form, and the contractual procedures associated with that form. However, a clean-cut separation of these two subjects could not be made, because when the simplified structure was developed, it became apparent that the primary distinguishing feature of these forms, as presented in Figure 3-1, was the party with whom the owner contracts. The functional capability of the forms can overlap significantly, with only the authority – i.e., agent versus independent contractor – differing. Using an example cited elsewhere in this report, the casual observer might find it difficult to differentiate between a project operated by a manager in charge of the owner's construction contracts from one operated by a constructor using construction subcontractors to do the work.

Figure 3-1. Basic Project Organization and Alternatives



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In light of the above, this section discusses 1) the potentially available contractual relationships and the functions commonly performed by the individual contracted parties in each of these relationships; and 2) procedural and contractual factors that can be expected in each form.

After this general discussion of the forms and their characteristics in Section 3, the forms will be described in greater detail in Sections 4 through 8.

3.2 PROJECT FORMS

There are many ways of approaching the performance of DESIGN & CONSTRUCT projects. The emphasis in this study is on the SINGLE-RESPONSIBILITY forms. Although the OWNER has the fundamental responsibility for the performance of his work, he may assign a major portion of that responsibility to a single CONTRACTOR. In view of the number of major contracting PARTIES involved in a project – the ENGINEER, the CONSTRUCTOR, and the MANAGER – the possible organizations can be limited to the four basic structures diagrammed in Figure 3-1. In this figure, a double-headed arrow represents a contract, and the overlap of a box and an arrow represents a third-party agency relationship. Most of the ways in which single-responsibility projects can be carried out can be shown to be variations of one or another of these basic forms. For comparison, Figure 3-1 also includes the traditional engineering: construction forms.

Lesser functions, which are not shown in the figure, but which might be contracted to additional parties, include PLANNING, START-UP, and operation.

In the definitions of project parties, no differentiation is made between parties that use their own forces and parties that subcontract any or all

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of the work. Also, it is likely that a party may handle more than one functional responsibility. For example, a party under a MANAGEMENT contract may subcontract for more than incidental CONSTRUCTION services. And since he is performing both management and construction responsibilities, he would be considered a constructor-manager.

Similarly, the owner may find it advisable to augment his technical capability by hiring consultants to provide engineering or other support during the planning or start-up PHASES and to interface with the several other parties. Throughout this discussion, whenever the owner is mentioned as the supplier of technical and commercial data, it is understood that he may have contracted for assistance in its development.

The traditional project form and the four basic single-responsibility project forms are defined below, and the latter are discussed in greater detail later in this report. The title selected for each form describes the function(s) of the contractor who is assigned the overall responsibility.

3.2.1 Engineering: Construction

Engineering:construction (E:C) is the designation applied in this report to the traditional method of performance of public works projects in which the DESIGN engineer and the constructor are separately contracted by the owner (see Figure 3-1A). E:C is not a single-responsibility method of organization in the sense of this report. It is described here only as a basis for comparison with other project forms. However, in an E:C project, the engineer has certain construction-phase responsibilities — primarily those associated with conformance to engineering drawings and specifications. In this regard, E:C is related to the engineering and management (E&M) form, but in the absence of a qualified construction supervision staff, it is erroneous to refer to E:C as an engineering and construction management form.

3.2.2 Engineering and Construction

The engineering and construction (EPC) form of project is the one most commonly used for single-responsibility contracts (see Figure 3-1B). In this form, a single party is contracted to perform both engineering and construction and is referred to as the engineer-constructor. Turnkey contracts fall into this category. The EPC form is frequently referred to as engineering-procurement-construction (hence the abreviation EPC) because the engineer-constructor normally performs the PROCUREMENT services as well as preparing material specifications and requisitions and handling the material delivered to the job site. Since procurement by the engineer-constructor, however, is not mandatory in this project form, the title "engineering and construction" is adopted in this report. The abbreviation EPC, because of its familiarity, is still retained.

3.2.3 Project Management

The project management (PM) form is one in which a party is contracted by the owner to manage the project – that is, to oversee on a third-party basis the efforts of other parties contracted by the owner to carry out the functions of the project (see Figure 3-1C). The project manager performs many of the owner's activities and acts as an intermediary to advise and assist the owner during the performance of these activities.

3.2.4 Engineering and Management

Engineering and management (E&M) is the project form that gives the engineer major third-party responsibilities in the owner's contract with the constructor (see Figure 3-1D). The E&M form differs from the E:C form primarily in the degree of responsibility assigned to the engineer during the construction phase. There can be considerable overlap of the E:C and E&M forms because there is no unique contractual element which differentiates them. In the E&M form, the engineer-manager is called upon to perform the activities of a project manager as well as a field engineer. The term E&M should be used only when it is the owner's intent

to contract with the engineer for full construction management services and when the engineer is qualified to perform such services.

3.2.5 Construction and Management

The construction and management (C&M) project form is the complement of the E&M form (see Figure 3-1E). In the C&M form, the constructor has the third-party responsibility to oversee the performance of the engineer, who has been contracted directly by the owner. In a C&M project, the constructor-manager has overall project responsibility, which includes sequencing the engineer's efforts to conform to the field requirements, fitting the engineer's performance into the overall plan, and assuring that the drawings and specifications are suitable and prepared on schedule for use by suppliers and construction groups. This project form is rarely used but is presented here because the constructor-manager can normally be expected to carry more overall project responsibility than the E&M contractor.

3.2.6 Project Management : Engineer and Construction

The project management: engineering and construction (PM:EPC) project form is not discussed in detail here, but is applicable in some cases. In this form, a manager (PM form) is retained to oversee an engineering-construction firm which has full project responsibility (EPC form). This is a powerful variation of the PM form combining the high degree of control of the PM form with the centrality of responsibility of the EPC.

3.3 CONTRACTOR SELECTION

In a single-responsibility project form, it is necessary to make an early selection of the expected responsible party so that continuity can be provided from design decisions to operational acceptance.

The selection method is influenced by the extent to which the scope of the work is developed or by the type of COMPENSATION basis required for the anticipated contract. In the project forms discussed, there are different problems of contractor selection, depending on whether the contract is for management, planning, engineering, or construction. If firm price bidding is required, the proposal basis must be very clearly defined. If a selection is to be made very early in the development of the project, compensation arrangements will be less firm. In the absence of firm price bidding, the owner's appraisal of the contractor's qualifications becomes rather important.

The owner has more latitude in contractor selection in the PRIVATE SECTOR than in the PUBLIC SECTOR. He may prequalify bidders, apply quantitative factors in the selection process, or select someone other than the low bidder. He is not required to make public disclosure of his selection process, and he may adopt a number of different compensation methods.

Methods of selection vary from simple negotiation with a single entity to complex competition involving many entities. There are basically three approaches: competitive price, competitive negotiation, and non-competitive negotiation. The competitive process of selection requires each bidder to submit a proposal in response to a specific list of criteria provided by the owner. Competition need not be strictly quantitative in nature (i.e., price competitive), but may involve negotiation in order to resolve qualitative factors as well as priced items. In the public sector, law and regulation generally require that the award of construction contracts be made to the lowest responsive bidder, with negotiation of adjustments to the bid after the opening allowed in some cases.

Selection procedures usually begin with a prequalification of bidders (if this is allowed) based on the owner's knowledge of the prospective contractors through previous experience, reputation, capabilities, current workload, and other such factors.

Upon completing the criteria for the proposal, the owner contacts a number of potentially acceptable candidates. Interested candidates are supplied the criteria and asked to submit a proposal. For private sector contracts and for public sector professional contracts, this proposal may discuss only qualifications or it may discuss both qualifications and cost. In the former case, the owner may use the proposals as a basis for selecting the two or three most qualified candidates, who will then be asked to enter into negotiations or to submit priced proposals, if appropriate.

Using these criteria as a guideline, the owner evaluates the contractor on the basis of a ranking system. Evaluation by the owner includes review of the extent of services, the proposed method of approach to the work, the qualifications of key personnel assigned, the method of organization, the related experience, the costing methods, and the amount of FEE (if required as part of the proposal).

During the negotiation phase that follows, the owner and the potential contractor work jointly to prepare mutually agreeable contract provisions and compensation terms. The owner may negotiate with only one prospect or, in the private sector, with several prospects simultaneously. In the latter case, the selection of the contractor becomes difficult because the acceptable middle ground of the various negotiations can differ markedly and make comparison difficult.

The major advantage of non-competitive negotiation over price competition is that it allows one to consider qualitative factors that could affect the overall cost of the work but that might not be easily quantifiable at the time of contractor selection. Among these factors are expected productivity, extent of surveillance and expediting required, proximity of contractor's office to the work, and optimum life cycle costs. Another advantage of non-competitive negotiation is that it tends to create an understanding

between the owner and the propective contractor early in the game, and this understanding reduces the likelihood of an owner-contractor adversary relationship developing.

3.4 COMPENSATION

Over the years, many different methods have been developed for establishing the basis for compensating a contractor and for providing suitable INCENTIVES for both the owner and the contractor to operate in an economical and responsive manner. The major forms are described in a general way in this section and more specifically in the sections that follow.

In establishing the compensation expected by a contractor for the performance of a design & construct project (whether a contract calls for fixed price or reimbursable cost compensation), one must consider the following major cost components:

- Salaries of technical, supervisory, clerical, and administrative personnel
- Payroll costs associated with salaries
- Other direct costs, such as travel, printing, communications, etc.
- Field labor wages and associated costs
- Subcontractors' compensations
- Construction materials and equipment
- Indirect costs
- Fee
- Incentives (plus or minus), bonuses, and penalties
- Contingency in one or more of the above to compensate for contributory risk and liabilities.

Several project-related factors influence the choice of compensation method acceptable to both the owner and the contractor. These factors include the

size and complexity of the project, the site conditions, the extent of commercial risk relative to the contractor's net worth, and the completeness of the scope of definition.

It is desirable to retain, at the earliest possible time in a project, a party that has overall project responsibility. It is also desirable to establish as firmly as possible the compensation basis for that contractor. As these two desires are in conflict, a balance is required. The degree of difficulty of striking this balance varies from one project to another. One method is to make provision in the contract for renegotiation of the form and method of compensation as appropriate project milestones are passed. For example, the contractor can be engaged on a REIMBURSABLE COST basis; then when the engineering scope is better understood, the fee can be converted to a FIXED PRICE, or percentage basis; and finally when the physical scope is better understood, the total compensation can be fixed or a target price set. This stepwise method of setting compensation can be specified in the original contract by incorporating appropriate compensation language and by specifying milestones.

There are basically two methods of compensation: (1) fixed price and, (2) reimbursable cost. Within these two broad categories there are a number of variations. Some of these variations are:

- Fixed price
  - LUMP-SUM – Competitive bid
  - – Negotiated
- Reimbursable cost
  - COST-PLUS
  - UNIT PRICE
  - Fixed Quantity

Optional terms which may be applied to any of these basic methods include GUARANTEED MAXIMUM PRICE, TARGET PRICE, target quantities, and incentive fee. Additionally, combinations of the above basic methods are sometimes used in a single contract (e.g., professional services, out-of-pocket expenses, material costs, and construction costs may each be compensated under a different formula). The most common applications of the basic methods of compensation are illustrated in Table 3-1.

Table 3-1

APPLICATION OF BASIC METHODS OF COMPENSATION

Method of Compensation	Contract Between Owner and: Engineer	Manager	Constructor
Lump-Sum, Competitive Bid			•
Lump-Sum, Negotiated	•	•	•
Percentage	•	•	
Cost-Plus	•	•	•
Unit Price for Material and Labor			•
Unit Price for Professional Services	•	•	

One of the best-known pricing methods is the lump-sum price, wherein the contractor commits himself to the performance of a specified scope of work for a fixed compensation.

A compensation payment schedule related to calendar time is generally associated with the lump-sum price. Frequently, in lieu of calendar time, percentage completion or specified milestones are used. This payment schedule, sometimes called "project cash flow" or "progress payments," is established to approximate the contractor's anticipated cost and/or commitment experience.

Under a reimbursable cost contract for engineering and management services, a percentage of the total facility cost is commonly used to establish a fixed compensation or to limit compensation. The "ASCE curves" are typical of several recommended methods commonly used in the public sector as a guide for setting the percentage. This form of compensation may be a percentage of either actual or estimated facility cost. The estimated cost can be used to establish a fixed-price compensation at an early stage. When the actual cost is used, the compensation is not fixed until construction costs are determined.

As a rule, the facility cost should be that portion over which the contractor exerts a direct influence. Thus, owner's costs of financing, staff, land, etc. are normally excluded, while the values of contracts managed, as well as costs of other services provided, must be considered for a manager's compensation.

In the cost-plus contract, the owner promises to reimburse the contractor for all costs associated with the performance of the work and to provide an agreed-upon fee, which may be either fixed (CPFF) or a specified percentage of the costs (CPPF).

There are two methods of converting costs to compensation. One calls for the reimbursement of actual costs experienced; the other uses unit prices approximating actual costs.

Unit prices are commonly established at levels approximating the contractor's DIRECT COST and may or may not include markups. Unit prices will frequently include INDIRECT COSTS and they may include fee as well. More complex projects do not lend themselves to combining indirect costs and fee components into unit prices because these components may be applied in differing ratios to different functions (e.g., field office salary expenses carry a different indirect cost ratio than do home office salaries).

In an alternative compensation method, one sets a fixed or target value for the amount or quantity of resources the contractor uses, i.e., materials or labor man-hours, and calculates the compensation on the basis of the actual costs of the materials and/or labor. This form makes the contractor responsible for quantity (the thing over which he has most control) and allows prices to be set by the marketplace.

Although not an incentive in the normal sense, the application of a guaranteed maximum price (GMP) to a contractor's compensation influences his cost consciousness, particularly as the forecast costs approach the GMP. The costs of performing required services that cause the contractor's expenses to exceed the GMP must be swallowed by the contractor. Savings are to the benefit of the owner. The GMP value is established by negotiation between the owner and the contractor and is usually some agreed-upon percentage over the estimated cost of performing the specified scope of work.

Because of its up-side risk and lack of down-side gain, the GMP is usually unpopular with contractors. This lack of popularity could be lessened if incentives were introduced into a GMP contract in the form of a participation by the contractor in some portion of cost savings below the GMP. There are those who suggest that the fact that the GMP is set at a level higher than the most probable cost is enough of an incentive for the contractor. This objection can be met by using a more complex incentive formula which provides an incentive if the actual cost of the work falls below some predetermined fraction of the GMP, rather than below the GMP itself, leaving a "dead-band" between the GMP and the incentive base.

An incentive system being used with increasing frequency in reimbursable cost contracts is the target price system. In this system, there is a sharing of savings or overruns relative to a target price value that is

established at or only slightly above the most probable cost estimated at an early stage in the design development. Sharing is normally equal, with the contractor's share of savings or overruns limited to an agreed-upon fraction of his base compensation.

A limited form of target price incentive is the "value engineering incentive" that is at present being applied to some government contracting. In this incentive scheme, the contractor shares 50 percent of the savings achieved as a consequence of the implementation of approved cost-reduction ideas developed during construction. A similar procedure has also been applied by some to the design phase. In this procedure, estimated overall cost savings or specific improvements are rewarded, giving the engineer (on, say, a lump-sum contract) incentive to spend more in engineering to gain a more cost-effective facility.

For a given job, the contractor's price will depend upon the compensation terms applicable. In general, a target price approximates the most probable cost, a lump-sum price is 5-10 percent higher than the most probable cost, and GMP is 10-20 percent higher than the most probable cost. The higher prices for lump-sum and GMP reflect the higher risks associated with these types of compensation. If desired, targets may be applied to quantities instead of costs.

In addition to incentives to perform within cost budgets, there are incentives applied to time budgets (see the completion guarantee below) in the form of bonus/penalty provisions for early/late completion. These usually involve a unit amount of adjustment to compensation for each day the completion precedes/follows a specified date. On projects of long duration, a grace period of several weeks is generally provided on either side of the scheduled completion date. Here again, the total adjustment of the contractor's compensation by this means is usually limited to some fraction of his base compensation.

3.5 RESPONSIBILITIES, GUARANTEES, AND LIABILITIES

The fundamental responsibility for a project resides with the owner. The responsibility of the contractor is established in the contract between the parties. The amount of responsibility that a contractor can assume is dependent on such factors as the authority granted to him, the number of activities he performs, the risks or factors beyond his control associated with the performance of these activities, and the amount of compensation he receives.

Both implied and explicit GUARANTEES of various sorts exist, but to prevent misunderstandings, as many guarantees as possible are explicitly included in the written contract. The guarantee is supported by the reputation and integrity of the contractor as well as by contract law.

The usual types of guarantees are:

- Performance
- Materials and workmanship
- Completion date
- Process

The PERFORMANCE GUARANTEE is implicit in any contract. It is commonly supported by holdback of compensation by the owner. In the public sector, and to a lesser extent in the private sector, performance bonds are required of all construction contractors.

The basic form of stated guarantee is the MATERIALS AND WORKMANSHIP GUARANTEE. This guarantee commits the contractor to assist the owner in enforcing suppliers' guarantees and warranties and is supported by the holdback of compensation provided for in the contract or by performance bond.

COMPLETION DATE GUARANTEES are not common. Since their function is to protect the owner against undue loss of profit and/or usage of the facility, they are usually supported by a bonus/penalty provision which establishes a per diem amount of payment to the owner/contractor for any schedule overrun/underrun.

The PROCESS GUARANTEE is also not common because:

- It is difficult to define in terms of actual conditions versus design conditions.
- The performance of the facility is related to external conditions, such as process feed or influent characteristics, that may change prior to completion.
- It poses a significant risk to the contractor and hence requires increased compensation.
- Expending additional effort to assure good design and construction makes more sense than pursuing a default in a process guarantee.

With the exception of some U.S. Government contracts, process guarantees in the public sector are rare. Recently, however, in response to bidding requirements in a few water pollution control projects, process equipment suppliers have offered limited process guarantees to constructors, through whom the guarantee flowed to the owner.

Support of a process guarantee can take many forms. The most stringent form, which is commercially impractical for large facilities, is to require the contractor to repair or replace the facilities, at his own expense if necessary, to bring the performance characteristics up to specification. The most common form requires redesign at the contractor's expense and modification at the owner's expense. Some process guarantees are similar to a performance guarantee, involving simply a commitment to maintain engineering and construction forces at the owner's expense until the facility performs to the owner's satisfaction.

In Europe, and to an increasing extent in the United States, process equipment manufacturers have provided process guarantees for process configurations that incorporate their proprietary equipment. In the past, these guarantees were limited to "packaged units," but it has become more and more common for them to cover unit processes or whole facilities supplied on an EPC basis.

When the characteristics of the material charged to the facility are well-known, a process guarantee can be supported by a liquidated damages formula establishing a financial penalty for falling below guarantee levels of certain produce values (e.g., dollars per percentage point of deviation from specified efficiency, dollars per unit of chemical required over specification, or dollars per incremental unit of power consumption). Frequently, the contract will provide premium compensation for process performance that exceeds expectations as well as penalties for process performance that falls short of expectations.

When entering into a design & construct contract, the contractor assumes a number of liabilities in addition to those associated with the guarantees discussed above. These include liabilities related to his possible negligence, liabilities for damage to the owner as a result of any act by the constructor or his employees (such as accident or error in employee judgment), and contingent or secondary liabilities from owner's losses resulting from but not directly caused by the contractor's actions. However, contractors rarely accept contingent liabilities because prior approximation for risk assessment purposes is difficult. In lieu of contingent liability, liquidated damages formulas are sometimes agreed upon for such things as failure to complete the facility on time; these formulas should reasonably approximate actual damages.

The contractor normally sets a limit on the magnitude of the liabilities accepted, mainly to prevent his being forced out of business by some extremely high-cost incidents. (The seeming precedent of small, low-net-worth contractors accepting unlimited liability must be viewed in the light of actual potential recovery under bonds, errors and omissions insurance, and the bankruptcy laws in the event of a major claim.) Liability limits are some fraction of the compensation received. Financial liabilities associated with guarantees, although limited, serve as commercial incentives to the contractor However, unsupported guarantees establish the contractor's intent to be responsible for that aspect of the work.

Insurance is commonly purchased to cover a large number of the normal risks. Directly or indirectly, the cost of such insurance appears in the contractor's compensation from the owner. Contract language establishes which party is responsible for deductible and uninsured risks.

While the fundamental responsibility for a project rests with the owner and his contractor, all who participate in influencing the technical or administrative nature of the project share or assume that responsibility, and this must be reflected in contract terms or compensation. The technical impact, the added costs, and the time delays resulting from governmental or public reviews and revisions can neutralize the contractor's responsibilities, voiding the advantages of the single-responsibility concept of project performance.

3.6 LAWS AND REGULATIONS

The laws and government regulations applicable to design & construct projects are quite extensive and vary from one locality to another. As a general rule, all contracts are operated under the commercial code of the state designated in the contract. The performance of corporations, partnerships, and consulting engineers is regulated at the state level, and corporate licensing, personal licensing, and permits are usually

required. In certain states, federal, state, and local legislation places restrictions on corporations that wish to perform construction work, engineering, or consulting services. In other states, only individuals and partnerships are permitted to practice engineering. There are a number of codes and precedents bearing on the responsibilities, liabilities, and obligations of various parties to contracts, particularly on the quality of engineering and construction. More information on laws and regulations can be found in later sections of this report.

In the public sector, some of the major provisions pertain to 1) the method of selecting contractors, 2) the requirements for the separation of engineering and construction activities, 3) competitive and nondiscriminatory bidding, and 4) public disclosure.

Certain federal requirements are applied to recipients of federal grant funds when these funds are used to assist development of public facilities, regardless of the method of project execution. Federal procurement regulations are found in the "Uniform Administration Requirements for Grants-In-Aid to State and Local Governments," OMB, Circular A-102. The regulations of most importance to the subject of this study can be briefly summarized as follows:

- All construction labor, materials of construction, and installed equipment must be procured by competitive sealed bids.
- Awards for facility construction must be made to the responsible bidder making the lowest responsive bid.
- No specification for bids in connection with public facilities shall be written in such a manner as to contain proprietary, exclusionary, or discriminatory requirements other than those based upon performance, unless at least two brand names or trade names of comparable quality or utility are listed and are followed by the words "or equal."

There are provisions in A-102 for the project officer to waive the requirement for competitive lump-sum bidding under certain circumstances, or for waiving the nonproprietary limitation.

The EPA regulations of direct concern to this study are those promulgated under Title 40, Protection of Environment, Chapter I, Environmental Protection Agency, Part 35, State and Local Assistance, as published in the Federal Register, February 11, 1974. These regulations indicate that the construction of federally financed facilities is usually accomplished in three steps (the analogous project phases as defined in this report are shown in parenthesis):

- Step One: Facilities plans and related studies (Planning Phase)
- Step Two: Preparation of construction drawings and specifications (Design Phase)
- Step Three: Fabrication and building of a treatment works (Construction Phase)

A minimal amount of engineering work is required to develop the information needed in an application for a Step One grant. This data should be available from current basin plans and/or metropolitan area-wide plans, as required under other EPA regulations. Many owners are qualified to prepare a Step One application without additional technical assistance.

The content of an application for a grant for design work (Step Two) is more detailed. Essentially, it is a submission of the work completed in Step One (Planning). Since several of the Step Two application requirements call for a significant amount of specialized technical and professional skill, most public entities must retain an engineer to develop the contents of this application.

An application for a grant for construction (Step Three) includes completed construction drawings and specifications, developed in Step Two, which can be used for bidding purposes.

The regulations also provide that a grant may be authorized for a combined Step Two plus Step Three project. In the current regulations, two forms of combined grants are described: the Step Two and Three, and the Step Two/Three. Of interest in this report are the Step Two/Three applications, which are for design & construct projects entered into on the basis of performance criteria and basic design, and which are followed by the submission of detailed engineering drawings and specifications for EPA approval before construction proceeds. The required detailed design review by the EPA and state approved agencies can be done progressively as designs are completed. Where state regulations are not consonant with federal regulations on this matter, they inhibit implementation of accelerated project schedules possible under a Step Two/Three approach.

Section 4

ENGINEERING:CONSTRUCTION

4.1 GENERAL DESCRIPTION

Engineering:construction (E:C) is the most commonly practiced form of project execution in the public sector. It is the norm for wastewater management facilities developed by state and local agencies.

The typical responsibilities of the various parties in an E:C project are illustrated in Figure 4-1.

The E:C form of project is also employed occasionally in the private sector, but in a manner that differs somewhat from that used in the public sector.

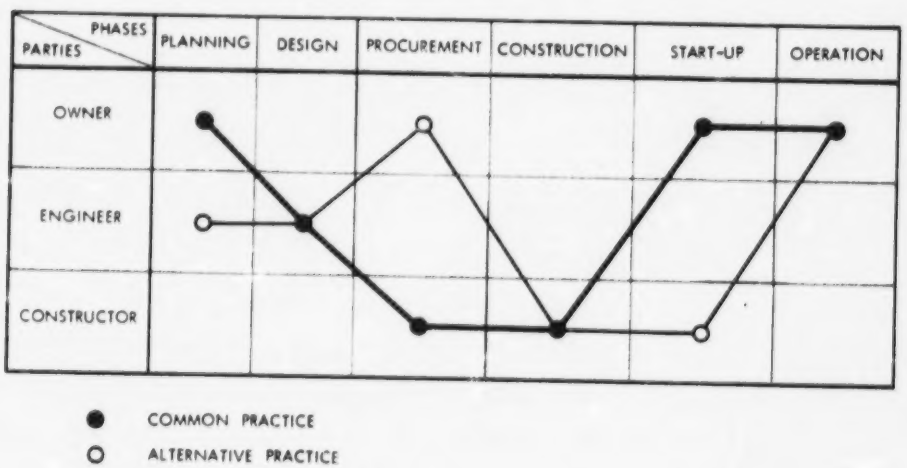

Figure 4-1. Typical Responsibilities of the Various Parties in an E:C Project.

Typically, in a private sector project, an engineer is retained because of his special qualifications and because of the owner's need to increase his technical staff so that it can handle the large task of preparing a definitive scope description and bid-request documents for use in subsequent bidding by potential constructors. The engineer's services are usually terminated immediately after the bidding documents have been submitted or (if he has been engaged to assist in bid evaluations) immediately after the construction has been selected. However, if the engineer is qualified to do construction, and the owner has no objection, the same firm may compete for and win the construction contract as well. In the latter case, the form becomes EPC (see Section 5) under two sequential contracts. Normally, an owner has sufficient engineering capability to oversee the work of the engineer and the constructor, and the E:C form is used in the private sector primarily to provide the owner maximum flexibility in selecting the best engineer and the best constructor for each phase.

In the public sector, the engineer is responsible for providing professional engineering services, including total responsibility for design engineering, and in many instances for planning as well. In addition, he usually bears some measure of responsibility as the owner's agent for providing engineering supervisory services during construction. This responsibility varies widely. In the case of a public owner with a large and sophisticated staff capable of construction management, the engineer's responsibility for the project execution may virtually cease once the owner accepts the detailed plans and specifications. If the public owner does not have in-house capability for construction management or if he recognizes the desirability of retaining the engineer in a more responsible role for execution of the project in conformance with the engineer's designs, the engineer is given a larger assignment during construction.

The usual practice is for the public owner (no matter how capable he may be himself) to require some degree of general supervisory responsibility by the engineer during construction. This takes the form of periodic inspections, approval of shop drawings, review of the constructor's monthly progress statements, participation in final inspection procedures, and general consultation during construction. On occasions, the engineer may be asked to provide continuous resident engineering and inspection service, to approve the constructor's change and extra-work orders, and in general to serve as the owner's agent in matters described in the specifications as "rights reserved to the owner." The engineer may also function as the purchasing agent for the owner when the latter has to furnish equipment, materials, and supplies. And finally, he may provide start-up, operator training, and performance evaluation.

When the engineer acts in a capacity requiring in-depth knowledge of construction practices, he is operating in a manner described in this report as the engineering and management project form (see Section 7).

The existing E:C method is characterized by a separation of the responsibilities of the engineer and the constructor. The engineer performs his planning or conceptual function and completes the design; competitive bids are solicited; a contract is rewarded; and the construction is performed by the constructor. As a result, the form is sometimes called "sequential engineering:construction."

The sequential nature of this form is sometimes modified by prepurchase of long-delivery major equipment and by preparation of multiple-design reports. This overlap of design and construction in the public sector is mandatory on very large projects and is normally undertaken by owners with competent in-house project management staffs that are capable of working with the contractor on complex problems. If the owner does not

have the necessary in-house management capability in a public sector project, this capability must either be engaged as a professional service (PM form) or must be assumed as an additional responsibility by the engineer (E&M form) or the constructor (C&M form).

Two major projects carried out under a form that resembles E:C more closely than any other form are: (1) the rapid transit rail system of the Washington Metropolitan Area Transit Authority, and (2) the Blue Plains wastewater treatment plant of the District of Columbia Department of Environmental Services.

The Washington Metropolitan Area Transit Authority has retained one firm to provide both preliminary (conceptual) engineering services and design engineering management of approximately 40 firms performing engineering design services, and has engaged the services of another firm to provide construction management of over 50 major constructors. In the case of the Blue Plains wastewater treatment plant, the planning and the design of a portion of the job were performed by one engineer, other portions of the design were completed by another engineer, and construction to date has involved ten or more constructors.

4.2 CONTRACTOR SELECTION

4.2.1 Engineer

In the public sector and to a lesser extent in the private sector, the amount of compensation is not a primary factor in selecting the engineer. The engineer does not bid for work, nor will he knowingly allow price to be a consideration in the determination of his qualification to do the work proposed. Only later, after a selection based on qualifications is made, is the price of his services considered.

Since price is not an initial consideration, the engineer's qualifications and availability are the principal basis for selection. The owner's task is to make an objective analysis of the qualifications of the engineers available and to select the one most competent for the project at hand. Normally, there are several engineers available, each with comparable qualifications.

In the public sector, engineer selection procedures are usually more rigidly constrained than in the private sector. Pertinent legislation on this subject includes the Brooks Bill, the Annual Military Construction Authorization Bill, state laws, and state board rules of professional conduct. In addition, several professional associations have suggested procedures concerning the selection of engineers for public sector projects, all of which rely on the concept of initial selection based solely on qualifications.

In the private sector, under the E:C form, the engineer may be selected rather arbitrarily by the owner on the basis of (1) the owner's prior experience with the engineer or (2) a proprietary process position held by the engineer. When more than one engineer is qualified, the owner may use any one of several contractor selection techniques involving proposals and direct negotiation.

4.2.2 Constructor

In the public sector, selection of the constructor under the E:C form is accomplished by taking competitive bids from constructors who have responded to a publicly advertised invitation to bid. Bids are usually received and handled in such a manner as to maintain secrecy until simultaneous public disclosure, and the contract is awarded to the low responsible bidder.

Because the design specifications under the E:C form are relatively detailed, the constructor in the private sector is often selected on the basis of a firm lump-sum price proposal based on the specifications. In many cases, however, his qualifications, past performance record with the owner, and other factors are often considered as well as price, and it is not unusual for private sector awards to be given to other than the low bidder. Industry ethics require, however, that the owner have cause for passing over the low bidder.

4.3 COMPENSATION

4.3.1 Engineer

Under the traditional E:C form of project execution, the method of compensation for engineering services can be determined in several ways, depending on the services provided, the custom or practice of the owner, and other factors. Normally, it is in the form of some reimbursable cost method, with or without a guaranteed maximum price (GMP). Lump-sum compensation may be used when the scope of the work can be completely agreed upon.

Oddly enough, in the public sector, ill-defined projects (e.g., planning phase conceptual studies, environmental assessments, feasibility studies, and other "front-end" consulting services) are frequently contracted on a lump-sum basis in spite of the fact that it is precisely this type of work for which it is most difficult to predetermine the scope of the project or the amount of work required. The reason lump-sum contracts are used in these projects is that it is felt that reimbursable cost methods do not provide the owner adequate control of the cost of the services. Hence, most federal agencies and many municipal agencies require that a guaranteed maximum price (GMP) be included in reimbursable cost contracts. From the engineer's standpoint, control of the scope of work under a reimbursable cost contract is not within his power, yet he is expected to assume the

risk of costs exceeding the GMP. As a result, he is more inclined to accept a lump-sum type of contract whose scope is carefully defined.

In the public sector, design phase services under the E:C form are most commonly contracted on one of the following bases:

- Lump-sum
- Percentage of facility costs (i.e., the ASCE curve)
- Unit prices up to the guaranteed maximum price

As long as the planning work is sufficiently detailed, it is possible to accurately determine the scope of the work for a design assignment and consequently to predict the type and amount of work required. For this reason, a lump-sum contract for design services is recommended and preferred by most engineers, although a unit price contract with a GMP is often acceptable. Both lump-sum and unit price contracts have many advantages over percentage of facility cost contracts and are becoming more common in public practice.

In the private sector, the engineer may perform his services under any of the forms of compensation described earlier. It is common in private work to use a reimbursable cost method constrained by an informal type of guaranteed maximum price, which, when approached or equaled, is subject to reevaluation between the parties before work continues. When the scope of the project is sufficiently defined, design work is often done on a lump-sum basis, particularly when a proprietary process engineer supplies the design of a processing unit in his field of specialization.

In the special case of licensed proprietary processes, the engineer may negotiate the cost of design in conjunction with the royalties or other considerations associated with the proprietary processes. Because of the

compensation received through a separate royalty agreement, the actual engineering compensation may not be commensurate with actual costs.

In both the public and private sectors, engineering services performed during construction are usually compensated for under a unit price method. The unit price method is employed because the amount of work required is difficult to predict and may depend on the constructor's or owner's actions. And both of these are beyond the engineer's control. Despite the difficulties in predetermining the construction engineering effort required, many municipalities insist on a guaranteed maximum price or lump-sum price, frequently based on a percentage of facility cost.

4.3.2 Constructor

In an E:C project in the public sector, constructor services are contracted for on either a lump-sum or a unit price basis. In some cases, the constructor is asked to furnish a unit cost breakdown of his bids that will provide individual prices for various items, including equipment, subcontracts, or other construction items that may be changed during the construction operations. This breakdown helps determine the value of progress payments, provides a basis for negotiating changes, and generally assists the engineer and owner in evaluating the bids and the constructor's operations. The award, however, is based solely on the amount of the lump-sum, and this sum determines the value of the contract.

Unit price bids closely resemble lump-sum bids. The chief difference between them is that in unit bids, the total project is broken down into units for which quantities are provided, and the bidder bids a price for each unit. The unit prices are multiplied by the quantities estimated by the engineer, and the sum of the unit cost extensions provides a total price which is used as a basis for comparison of bids.

Single-facility installation (e.g., pump stations and treatment plants) requiring complex construction operations, large amounts of installed equipment, and several distinct operations (e.g., structural, mechanical, and electrical work) are usually bid on a lump-sum basis. On the other hand, projects that call primarily for the application of construction labor and construction equipment are usually bid on a unit price basis.

In the private sector, lump sum price and unit price construction contracts as described above are commonly used. However, while the E:C project form lends itself well to the solicitation of lump-sum proposals from constructors, in the private sector other compensation forms may also be applied. For example, the owner may want the constructor involved as early as possible in the project and, consequently, may retain him prior to the completion of the design work by the engineer. A typical way of accomplishing this might be the "fee bid," wherein the constructor is given an approximate description of the scope of the total facilities and the scope of his services, from which he estimates the degree of involvement and sets a firm fee to be applied in a cost-plus fixed fee form of compensation.

4.4 RESPONSIBILITIES, GUARANTEES, AND LIABILITIES

4.4.1 Engineer

In the public sector, under the E:C project form, the engineer assumes little or no contractual liability for process performance of the facility. As a rule, he guarantees only optimum professional effort and freedom from errors and omissions that relate to the physical integrity of structures and components. It is generally considered unprofessional to provide financial guarantees, because the engineer does not accept employment based on price considerations, and his incentive for good performance is the maintenance of his reputation and the anticipation of continuing work. When process guarantees are offered, they are limited to redesign services required to correct deficiencies.

It is apparent that planning studies do not carry process guarantees and can be performed only on a "best effort" basis. To limit guarantees in the design engineering phase to simply a "best effort" basis is increasingly coming under attack in the courts. When considering such questions in the recent past, the courts have held that the engineer does have a process guarantee responsibility. The increasing difficulty of acquiring errors and omissions insurance and the rising premium costs associated with this insurance attest to the changing nature of this matter.

In most cases, the private sector guarantees by the engineer are very similar to those in the public sector, except that in the private sector the engineer is usually expected to provide some form of process guarantee.

4.4.2 Constructor

Under the E:C form, in both the public and private sectors, the constructor's function is to construct the facility in accordance with the engineer's plans and specifications and within the time and price constraints specified in his contract with the owner.

Constructors in the public sector have historically been required to guarantee their work in accordance with the plans and specifications (performance, materials, and workmanship guarantees). In fact, most governmental entities have regulations stipulating that constructors provide bonds as security. The amount of the bonds is commonly 100 percent for performance and 50 percent for material and labor. The bond requirement relates to the timely completion of services with good workmanship, to the quality of materials and equipment applied to the project relative to the engineer's plans and specifications, and in the absence of specified standards, to generally accepted industry standards. If the constructor purchases specified equipment, he assumes the responsibility for pursuing the manufacturer's warranties pertaining to the equipment. If on the other

hand, the equipment is purchased by the owner, the constructor assumes responsibility only for the quality of installation.

In the private sector (as in the public sector), the general absence of facility design or process design responsibility by the constructor limits the guarantees to the normal materials, workmanship, and performance guarantees. In addition, the requirement that the constructor provide bonds may not exist or may be waived.

4.5 LAW AND REGULATION

There are no laws and regulations applicable to E:C projects performed in the private sector beyond those previously discussed.

4.5.1 Federal Laws and Regulations

In the public sector, there are no federal laws that unduly inhibit the E:C form of project execution beyond those described earlier concerning competitive bidding. E:C is, in fact, the most popular form and is actually required under many existing laws.

The E:C form is consistent with EPA regulations in that it separates the preparation of construction plans and specifications (Step Two) from the construction (Step Three). And according to these regulations, a separate grant can be made for each step. The E:C form is also suitable for Step Two/Three projects, whether carried out in a sequential or in an accelerated manner.

4.5.2 State and Local Laws

State and local laws concerning execution of public projects are compatible with and reinforce federal requirements. Concepts embodied in federal law tend to be amplified by state law and are frequently carried forward in a more restrictive manner.

Most states require competitive bidding for construction work, require that the award go to the lowest bidder, and place restrictions on the use of proprietary, exclusionary, or discriminatory language in specifications. The previous discussion regarding the effect of similar federal requirements on the E:C execution method obviously applies to state and local laws as well.

4.6 SUMMARY

Engineering:construction (E:C) is the traditional method of executing projects in the public sector. The method is characterized by a sharp separation between the engineering function and the construction function, with the engineer and the constructor separately contracted for by the owner.

The engineer is employed on a professional basis to perform services and normally does not bid for work. He is responsible for all planning and design activities and may have some supervisory responsibility over construction as an agent of the owner. The engineer guarantees his work against errors and omissions, but does not contractually provide process guarantees.

The constructor makes competitive bids that are based on detailed plans and specifications. In the public sector, bids are either lump-sum or unit price, award is made to the lowest responsible bidder, and the bids are secured by bonds. The constructor is usually expected to provide performance guarantees and materials and workmanship guarantees and is frequently responsible for pursuing equipment warranties. He does not contractually provide process guarantees since he has no part in the design.

There are no federal, state, or local laws or regulations which unduly restrict the E:C method.

Section 5

ENGINEERING AND CONSTRUCTION

5.1 GENERAL DESCRIPTION

The engineering and construction (EPC) form is the most commonly practiced form in private sector construction of process facilities of small and intermediate size. Very large projects (over 100 to 200 million dollars) are often beyond the staffing and financial capabilities (if lump-sums compensation is required) of a single engineer-constructor. These large-scale projects can be divided among several EPC contractors that are contracted with the owner and managed by the owner or a project manager. This is the PM:EPC form described earlier.

The typical responsibilities of the various parties in an EPC project are illustrated in Figure 5-1.

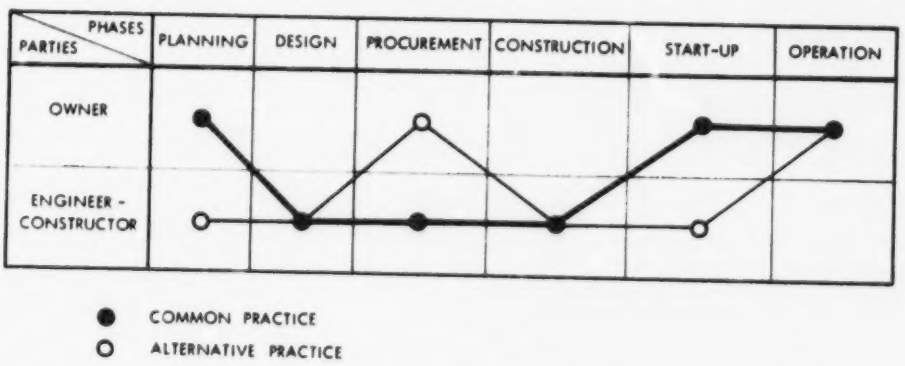

Figure 5-1. Typical Responsibilities of the Various Parties in an EPC Project

A distinguishing characteristic of the EPC form is that the contractor is free to proceed with the purchase of equipment and materials and with construction activities as soon as they are adequately defined in the engineering phase (barring legal or regulatory restraint). There is no time loss due to design information retention (for design report preparation) and to subsequent constructor lead-time requirements. An exception to this occurs when the EPC contractor finds it advantageous to give certain portions of the work to subcontractors, but time can be saved by obtaining unit price bids from subcontractors on preliminary design information rather than awaiting final detail design.

The EPC form is used in municipal wastewater treatment projects only to incorporate package facility elements. Frequently these components are of a proprietary nature. When the size of the facility is small, these elements may constitute essentially the total facility. These small projects, which can be developed with package plant elements, are a separate class of project exempted from the general prohibition of the EPC form from public sector work.

Several federal agencies allow the use of EPC project forms for package units. (These units may be quite large.) The Department of Defense, for example, recommends this method of procurement for package-type wastewater treatment facilities. With this exception, the EPC form of project is virtually nonexistent in the U.S. wastewater management field.

In Europe, EPC procedures are commonly used in constructing wastewater treatment facilities and the equipment supplier is commonly the EPC contractor. In the U.S., the suppliers provide the small package units and recently have begun furnishing whole processing units on an EPC basis, incorporating their equipment when applicable.

5.2 CONTRACTOR SELECTION

The selection of an EPC contractor normally follows the planning phase. The contractor is retained at the beginning of the planning phase only if he is able to handle the complexities of the developmental and planning work. If such a firm is retained to help with the planning, it is on a negotiated basis, with the understanding that at a later date the firm will be allowed to negotiate for engineering and construction (private sector) or to bid for the remainder of the project.

In a sense, EPC resembles the construction phase of the E:C form in that the owner prepares, or has some other party prepare, a set of bidding documents suitable for the solicitation of proposals from contractors. In fact, however, the differences are significant:

- The EPC proposals are solicited on the basis of criteria and general specifications developed in the planning stage, rather than on the basis of the detailed plans and specifications produced in the design phase.
- When lump-sum bids are required, instead of using completed designs, the bidders do a great deal of engineering, obtain equipment bids, and prepare a definitive cost estimate upon which to base their proposals.
- A significant amount of engineering is included in the scope of work of the contractor.

In private sector lump-sum EPC bidding, the prospective contractors' design work procurement effort and the cost estimating required for a proposal may take three to five months and cost up to several hundred thousand dollars each for major jobs. Occasionally, the owner will offer to compensate unsuccessful bidders (preselected) for all or part of their proposal costs to preclude qualified candidates from declining to bid for

financial reasons. Because of the advanced stage of design and procurement at the time of award, the project begins very promptly once the award is made. However, in the long run, owners pay the bidding costs in incrementally higher project costs.

Some federal programs provide for prequalification of a list of potential EPC contractors based on submitted statements of qualifications. Prospective contractors so prequalified are then asked to submit detailed proposals containing preliminary designs and facility specifications, a firm price and completion schedule, and any other information necessary to characterize their offer. The contractor who offers the least-cost (first or life cycle) facility, considering both price and quality, is selected. Different agencies of the federal government have different selection procedures: some agencies allow negotiation with one or more of the proposers prior to selection; some depend more on bid price; and some rely heavily on the quality of the proposal.

In the bid review, the owner reviews the details of the facility designs submitted by the bidders. The following kinds of comparisons are made: conservatism in design, use of known processes, economic tradeoff of operating versus capital costs, ease of maintenance, future expansion capability, operating flexibility, and in the private sector a subjective evaluation of quality of design, equipment selection, and relative contractor capability.

The owner then enters into discussions with one or more of the bidders to 1) clear up exceptions or to 2) modify the scope of the work to better suit his needs and desires or to bring competitors to a more common basis. During this period, the contractor may find it necessary to adjust his bid price to reflect revisions requested by the owner.

These revisions may change the ranking of the bidders. Unless significant changes develop, the bidding procedure is seldom repeated and once the proposals are technically and commercially acceptable, the owner selects the lowest bid, as adjusted.

The procedures recommended by the DOD for EPC contractor selection are:

- One-Step Competitive Negotiation. One-step procedure provides for the competitive evaluation of priced technical proposals, with the award decision based on the optimum combination of technical merit and price rather than on the lowest bid price. The agency enters into negotiations with the most promising bidders to reconcile minor deviations from criteria. Detailed comprehensive evaluation criteria are used which provide the means to competitively evaluate the quality of the technical proposals as measured by functional life cycle costs, aesthetics, and other considerations as may be indicated. One-step procedures are appropriate for use in the acquisition of facilities in which a wide variety of acceptable solutions are available.
- Two-Step Formal Advertising. The use of two-step formal advertising is considered appropriate in situations in which it is possible to prescribe, through the use of performance specifications, readily available commercial products and/or expertise which will satisfy the project requirements. The first step is the submission of a technical concept proposal. The second step is the submission of price proposals by all those offering acceptable technical concept proposals.

For a more detailed description of the DOD procedures, see Department of Army "Interim Guidance for Two-Step Construction Contracting," July 9, 1971, and ASD (I&L) memo, dated November 27, 1972.

5.3 COMPENSATION

There is a tendency to equate lump-sum compensation with the engineering and construction project form, but the EPC form can have terms of compensation other than lump-sum. It is true that of the project forms discussed in this report the EPC form lends itself most conveniently to lump-sum compensation for the total project. But as in any of the project forms, the compensation method agreed upon between the parties is that which best satisfies the needs and desires of the parties.

Public sector EPC projects are compensated primarily on a lump-sum basis, established by competitive pricing analysis which determines the least overall cost. The lump-sum amount of the contractor's bid then establishes the value of the contract and consequently the amount of his compensation. Lump-sum compensation is inappropriate in projects that might go beyond the state of the art. In such projects, compensation could be on a reimbursable cost basis for all portions of the work or for just the engineering.

EPC work need not always be on a lump-sum bid price basis. One popular and mutually desirable compensation method involves a multi-step procedure through which the contractor is compensated as the project proceeds. The following example illustrates one such case. It is drawn from the private sector.

The owner engaged an engineer-constructor on a reimbursable cost (unit price) basis to perform the planning phase, which consisted of two parts: the first part involved rather general conceptual studies and decisions and lasted approximately one year; the second part was devoted to a definition of the process design. After the planning phase was completed, the engineer-constructor spent about six months on the design effort, also

on a cost reimbursable basis, until a definitive facility cost estimate could be prepared. By the terms of the original contract, the parties had agreed to establish a firm or target price, at the owner's option, for the supply of equipment and materials and for the construction of the facilities, the price to be based on the definitive cost estimate prepared by the engineer-constructor and thoroughly reviewed by the owner. Upon completion of the planning phase, the scope of the project was sufficiently defined to allow a lump-sum price to be determined. But because the facility interacted so intimately with existing processing facilities, the owner selected the CPFF terms in order to maintain maximum participation in the project effort.

5.4 GUARANTEES AND LIABILITIES

The obligations of the engineer-constructor under the EPC form are a combination of the engineer's and the constructor's guarantees and liabilities as described in the earlier sections. Process guarantees are frequently specified in private sector process plant contracts and in certain federal projects.

The performance and process guarantees are usually secured by significant holdback of compensation by the owner. Performance bonds are normal in the public sector. The contractor's completion schedule may be secured by liquidated damage or bonus/penalty provisions.

Proprietary or exclusive know-how is particularly well-handled by the EPC form of project when it is applied to facilities that may be supplied by a process licenser in a manner similar to a piece of complex major equipment. These facilities might be complete package units or components of a larger facility, assembled on site by the engineer-constructor. In the former case, the proprietary supplier would be the engineer-constructor; in the latter case, the proprietary component might be supplied to the EPC contractor on a subcontract basis.

An attractive characteristic of manufacturer-supplied processes is that the suppliers frequently offer process guarantees not available from competitive engineers or engineer-constructors who do not have proprietary equipment or processes. Since the process contractors have as a rule spent a good deal of money to develop and test their product line, a portion of this cost must be recovered in their compensation. However, this value-added component in their compensation gives them a stronger financial base for support of guarantees. There are two major disadvantages of using proprietary offerings: 1) they are unique, which makes it difficult to perform a comparative evaluation of competitive offerings, and 2) they may require other products that can be furnished only by the same supplier.

For both the small unit or the large process complex, the engineer-constructor can expect to be asked to provide a process guarantee, including "flow-through" of subcontractors' guarantees.

5.5 REGULATIONS

There are no laws or regulations exclusively applicable to the EPC project form in the private sector. The remainder of this subsection discusses public sector considerations.

5.5.1 Federal Laws and Regulations

As applied to EPA, federal procurement rules, not law, usually prohibit the EPC method of project execution. But as has been pointed out earlier, there are conditions under which this method of procurement may be allowed or encouraged. Procurement rules generally forbid the use of a single-source, non-competitive supply, but an EPC contractor selected by competitive bid is free of this limitation and may select those he will be willing to guarantee. The contractor wishes to retain the right to use what he has

greatest confidence in, whether or not it involves application of proprietary or single-source items from his own supply or from others. The procurement rules constitute a restraint to other project forms because a non-competitively selected contractor, such as the manager, is not normally able to make arbitrary judgments, even if in his opinion, they are in the best interests of his client.

EPA regulations stipulate that if an application is made for a design & construct project, the application need not include construction drawings and specifications but may instead contain proposed performance specifications and other relevant criteria.

As envisioned in the regulations, the EPC form of project execution is clearly a design & construct project. Therefore, in using this method, an applicant can make a combined application for funds for design (the preparation of construction drawings and specifications – EPA Step Two), and for construction (EPA Step Three). As a prerequisite, he must complete all of the planning activities itemized in the reguations, as required for a Step Two application.

Under the combined Step Two/Three grant, the owner and contractor may proceed with plans and specifications for equipment and construction that may be most convenient for phasing and overlapping of design and construction, submitting them for state and EPA approval as they become available.

5.5.2 State and Local Laws

Some states have laws concerning public projects that are more restrictive than the federal rules. For example, several states apparently specifically prohibit the EPC method as defined in this report. In addition, certain states require approval of detailed plans and specifications before the

construction award is authorized, whether or not federal regulations call for them. And since performance specifications may not satisfy the requirement for prior approval of detailed plans and specifications, the EPC method is severely constrained in these states.

As has been mentioned earlier, some states have statutes or registration law provisions that prevent engineers licensed in those states from submitting competitive bids in connection with professional services. In these states, an EPC contractor who offers engineering services under a competitive price situation might be considered to be operating unlawfully.

5.6 SUMMARY

The engineering and construction (EPC) project form is the major single-responsibility method of performing design & construct projects. It has been used effectively in the private sector, where the owner has considerable latitude in methods of contractor selection and compensation and is not burdened with laws and regulations that limit his choice of action or that require him to make public disclosures. In the public sector, the EPC form is rather uncommon, and with the exception of package units, it is not practiced in the municipal wastewater management field.

Since the EPC contractor is directly responsible to the owner for virtually all activities in the project, time can be saved by overlapping design and construction activities. And since the EPC form can be bid on a competitive lump-sum basis, it can conform to existing public procurement rules. While it does not appear that federal law prohibits the EPC method for public works projects, some state and local statutes do so, either directly or indirectly. However, present EPA regulations specifically provide for the EPC form as an acceptable alternative.

The primary reason for the success of certain federal and private sector efforts employing the EPC form is the staff capability available to plan,

monitor, and manage projects executed this way. Most municipal entities involved with wastewater facilities lack such capability.

A disadvantage of lump-sum EPC is that the relative autonomy of the contractor obliges the owner to maintain a strong organization or retain qualified consultants to assist in the administration of an EPC project. Another disadvantage of lump-sum is the effect of delays, such as from EIS, intervenors, etc., upon the firmness of the price. A negotiated compensation basis, with provision for such delays, can result in a more economical job.

A major advantage of EPC is its ability to apply staged compensation methods – that is, the setting of the price (TP or LS or GMP) and compensation incentives for each phase of the project as the scope of that phase becomes apparent. Although staged compensation can be applied to other project forms, it is most advantageous in EPC because the engineer-constructor is directly responsible for all the work and does not need to depend upon other contractors (except, of course, his subcontractors) for cost and schedule data.

Section 6

PROJECT MANAGEMENT

6.1 GENERAL DESCRIPTION

The project management (PM) form of project execution for public projects has appeared in recent years. Several variations of the approach have been used and more are being developed.

The typical responsibilities of the various parties in a PM project are illustrated in Figure 6-1.

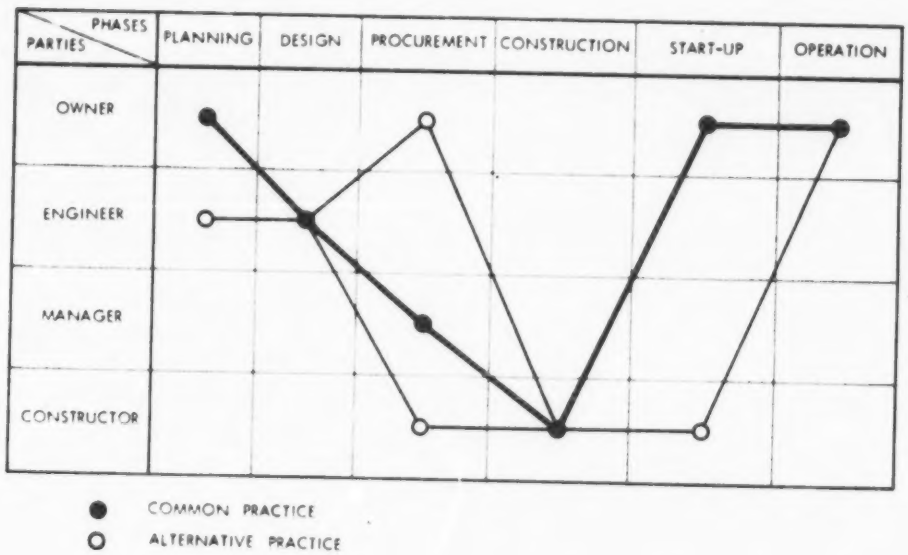

Figure 6-1. Typical Responsibilities of the Various Parties in a PM Project

The PM project form has become quite common as a method of project execution in the public sector. Although relatively new as a concept, it is now the method of choice of many agencies of the federal government,* particularly those agencies (such as GSA) that construct facilities directly for the government's account. It is also a preferred method of DHEW for third-party applicants using federal funds for public projects (hospitals, schools, etc.).** Many medium-size and large-scale projects (costing between 50 and 100 million dollars) have been performed using this method. And many federal agencies have either adopted the PM method as an alternative or are in the process of doing so.

In the PM form, a manager is contracted to oversee the efforts of the engineer(s) and constructor(s) and any other parties contracted by the owner. The project manager does the following:

- Provides technical consultation to the engineer and the owner
- Prepares a project schedule
- Establishes and monitors a project budget
- Prepares a project cash flow
- Provides or assists in supporting fields surveys, subsurface investigations, etc.
- Provides procurement assistance
- Prepares bidder's lists for contracts to be let
- Prepares invitations for bids; arranges prebid conferences and postbid conferences with potential contractors and suppliers, where advisable
- Provides field labor only to the extent required to carry out his own function

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* The method is frequently known to federal agencies as "Construction Management."

** See Technical Handbook For Facilities Engineering and Construction Manual, Part 2, "Guide For Project Applicants Construction Management Services," DHEW.

- Guarantees the input of construction-related factors in the design
- Maintains a field office and supervises field activities
- Coordinates the efforts of other contractors
- Monitors and schedules the constructor's work
- Recommends adjustments to field procedures to accommodate changing conditions
- Provides or coordinates with the engineer the means of inspection of workmanship and material
- Arranges for field delivery and tests
- Receives contractor reports and prepares a manager's report on work progress
- Reviews progress payments and makes recommendations to the owner
- Reviews all contractors' change proposals, coordinates with the engineer and makes recommendations to the owner
- Coordinates labor relations
- Provides for overall job-site safety and security

The prime purpose of the PM form is to combine engineering, construction, and procurement know-how into a management team involving the owner, so that the formerly separate functions can be integrated into one organization with overall responsibility for the successful completion of the project. The manager works as a team member with the owner, the engineer, and the constructor during the design and construction phases.

Many public PM projects (usually hospitals, schools, universities, airports, and similar facilities) are undertaken by owners who are recipients of federal funds but who do not have the large and sophisticated staffs necessary to provide the management required. In these cases, the owner retains a manager who serves as an independent contractor and furnishes project management services.

The World Trade Center of the New York Port Authority is an example of the PM form applied to a major project. An experienced engineer-constructor was retained as project manager to direct construction management, scheduling, expediting, procurement, and to advise two A&E firms on the impact of those functions on the planning and design phases. Over 170 separate constructors were contracted.

Another example is the GSA project for the 40 million dollar Air & Space Museum for the Smithsonian Institute. An A&E was chosen by GSA using conventional procedures. A construction manager was then selected by competitive negotiations. Technical (Qualifications) proposals were solicited, and the firms that submitted the best technical proposals were asked to submit price proposals. The technical proposal was weighted at 60 percent, the price proposal at 40 percent. The construction manager worked closely with the A&E in design, advised GSA of long-lead items that required governmental procurements, and inspected construction performed on a fast-track basis with 33 contractors.

Despite the apparent advantages of the PM method, it has seldom been used by municipal entities for development of wastewater management facilities. The authors are aware of only two major projects of this type being developed under a modified form of the PM method.

The above comments on the PM form in the public sector are for the most part applicable to the private sector as well. The PM form of project is used in the private sector primarily on extremely large projects which involve a multiplicity of design and construction contractors and which cannot be adequately managed by the owner's staff.

6.2 CONTRACTOR SELECTION

6.2.1 Engineer

In either the public or private sector, under the PM form the engineer contracts directly with the owner to provide professional engineering services. If the project has not been well defined previously, a major emphasis must be given to the preliminary engineering function, and this activity may proceed entirely outside of and prior to project initiation. In this event, the planning services may be performed by an engineer other than the design engineer. (Such an occurrence, however, is uncommon.) In most instances, the engineer who does the design also does the planning, either under a separate contract or as a distinct initial subphase of the design contract.

Under the PM form, the engineer is selected and employed on the same basis as under the traditional E:C form of project execution. But in the PM form, he works through the project manager, who is responsible for design and construction, rather than with the owner directly. If the engineer is hired to perform planning prior to the selection of the other project team members, the owner must evaluate his capability and willingness to cooperate with the project manager during project execution.

6.2.2 Project Manager

In both the public and private sectors, manager candidates are expected to be very proficient in engineering, budgeting, cost estimating, scheduling, purchasing, inspection, management, and labor relations. In addition, all the firms involved must have records of successful performance in furnishing professional services during the project design phase and in managing the construction.

At about the time that design engineering is initiated, a project management contract is executed between the owner and the manager. Like the

engineering contract, this is a professional services contract. A significant feature of the PM method is that the manager has some degree of supervisory responsibility over the engineer. The manager also has broad supervisory, managerial, and administrative authority over the construction program performed by the constructor(s).

The initial selection of the manager is seldom based on competitive bids or price considerations (in fact, government agencies frown upon selections so based) and the manager is usually chosen in a manner similar to that previously described for engineers. That is, the qualifications of several firms are examined, and a preselection is made of a few firms that are then asked to submit formal qualification proposals. These proposals do not normally include pricing information and are intended to further demonstrate the firm's ability to handle the specific project.

In the private sector, under the PM form the selection of a manager is based primarily on his qualifications and experience and on his compatibility with the owner. The owner generally chooses his manager during the beginning of the planning phase, recognizing that compensation terms may have to be left open until the overall scope of the work is known. However, at this early stage of the work, it is common practice for some agreement to be reached as to the compensation formula that would apply both in the initial phases and for the total project. This is done in order that the manager's compensation can be negotiated more readily once the scope of work is understood. The nature of the manager's compensation formula may be a factor in the selection of the PM contractor.

6.2.3 Constructor

In the public sector, the bidding on construction contracts must be conducted to maximize competition among qualified bidders and to obtain the

most reasonable price for acceptable work. Therefore, under the PM form (as in the traditional E:C form) competitive bidding by public advertising is the usual method of selecting constructors. In the private sector, competitive bids and contract awards need not go to the lowest responsible bidder. The result is much greater flexibility in selecting constructors.

6.3 COMPENSATION PRACTICES

6.3.1 Engineer

The compensation the engineer receives and the methods of determining this compensation are traditional, but as a rule less use is made of the percentage of facility cost as a means of setting fees. It is more common for the engineer to be paid on the basis of a negotiated lump sum or on unit costs. The engineer's compensation for design services are somewhat less than would be normal under an E:C project because of the contribution of the project manager. And his compensation for services during construction are often significantly less because of the assumption by the project manager of many of the engineer's traditional duties.

6.3.2 Project Manager

The compensation for project management services is normally based on either a percentage of the facility cost or on reimbursable costs.

It may not be in the interest of the owner to enter into an open agreement with no limit on fee or reimbursable costs for the manager's services. The compensation may be phased with the project: a specific lump-sum amount can be negotiated as the compensation for services during the design phase, and a separate lump-sum compensation can be set for the development and implementation of a management control system on those projects where a significant expenditure is required for such a control system. On smaller projects, the cost of the management control system may be included in the basic fee of the project manager.

For the balance of the project costs, the project manager might be expected to provide a target price (TP) or guaranteed maximum price (GMP). This is usually required when the project is to be completed in an accelerated manner, with an overlap design and construction. In this way, the owner avoids the risk of entering into a project and making major financial commitments without firm knowledge of his ultimate obligation. The price of the work would be agreed upon only after enough of the design has been completed and enough bids have been taken on major equipment items to permit a definitive estimate to be made.

6.4 RESPONSIBILITIES, GUARANTEES, AND LIABILITIES

6.4.1 Engineer

In general, the engineer's responsibilities for design are the same under the PM as under the traditional E:C method. His responsibilities for construction are minor.

6.4.2 Project Manager

In all the management forms (PM, E&M, and C&M), the manager usually assumes some form of responsibility for cost and schedule, and some increase in the manager's compensation can be expected with these guarantees. Those activities not directly under the manager's control will not normally be significantly underwritten by him. (Sometimes, however, contractor-performed activities that he does not control have guarantees that "flow through" him.) The manager may be willing to provide guarantees if he has the option, in the event of unanticipated difficulties, to assume the performance of the work with his own forces or his subcontractors.

Construction performance bonds may be furnished by either the individual constructors in the amount of their contracts or by the project manager.

If the project manager furnishes the bonds, he may, in turn, require the constructors to provide him with guarantees secured by bond for their respective portions of the work. Process guarantees usually are not provided by the manager; he does, however, pursue the engineer's process obligations and the equipment suppliers' and manufacturers' warrantees.

In the private sector, the same guarantees are available from the project manager as may be required in the public sector. However, much more flexibility is possible; performance bonds may not be required or may be waived in the interest of reducing costs.

6.4.3 Constructors

In both the private and public sectors, under the PM method the contor's responsibilities are to all extents and purposes the same as under the traditional E:C form.

6.5 REGULATIONS

6.5.1 Federal, State, and Local Laws

Public projects executed under the PM form encounter no difficulties that are due to federal, state, or local regulations. And there seems to be no reason why the use of this form should be restricted by the requirement for competitive, sealed construction bids or for award to the low responsive bidder. The fact that the method is presently used for many types of public projects for federal, state, and local agencies is proof of its legality and feasibility.

In the private sector, there are no laws or regulations, except those previously described, that are uniquely pertinent to the PM form.

6.5.2 EPA Regulations

As discussed earlier, two methods of handling projects are provided for in EPA regulations: 1) as a traditional sequential project using the two

step application method, or 2) as a combined design & construct project using the Step Two/Three procedure. The PM form is applicable to both.

6.6 SUMMARY

The project management (PM) form is now approaching the traditional E:C form in popularity as a method of executing public works projects. It is recommended for use by many federal agencies, including DHEW which, like EPA, furnishes grant funds to local municipalities for public projects.

The method provides single-project responsibility, with the project manager serving the owner's interests with respect to the engineer(s) and the constructor(s). It offers a means of bringing strong, knowledgeable project administration to bear on the assignment. Because of this capability, complex projects can be successfully accomplished in a multi-phased manner in which design, procurement, and construction overlap.

If the project manager has the required construction experience and financial capacity and is given sufficient construction control, he can provide the owner with some type of cost guarantees in the form of target price or guaranteed maximum price. This is a safeguard for the owner usually unavailable in a multiple construction contract method ("flash-trade") under E:C. The PM method offers all the other guarantees available under the E:C form, at least on a "flow-through" basis, but like the E:C form, it does not provide significant process guarantees.

Since the project manager and the engineer under the PM method are separately retained by the owner to perform professional services and have no financial interests in the constructor's operations, the traditional separation of interest between construction and engineering is maintained.

Under the PM method, the responsibility for innovative design and the application of new technology reside with the engineer and to a lesser extent, the manager. And because of the technical capability of the manager, the owner may be more favorably inclined to accept new and innovative ideas proposed by the engineer and approved by the manager.

There are no legal restraints that unduly restrict the PM method in either the private or public sectors. It would appear that the method can be used under the EPA regulations, to execute projects in either a conventional manner or as a combined design & construct project.

Section 7

ENGINEERING AND MANAGEMENT

7.1 GENERAL DESCRIPTION

Engineering and management (E&M) is used extensively in both the public and private sectors. It has been described in a previous section as a form that extends the construction supervision aspects of the E:C form. By the same token, E&M is a variation of the PM form, whereby the engineer undertakes the management of the total project, as described in Section 6. Construction is performed by separate constructor(s) contracted by the owner. As a result, the E&M form does not materially change the separation of design and construction functions characteristic of the E:C form, but it does increase the engineer's responsibilities to the owner and requires the constructor to be responsive to the engineer in overall project performance.

The typical responsibilities of the parties in an E&M project are illustrated in Figure 7-1.

Some of the characteristics of the E&M form are:

- The engineer assumes a greater project management role than is usual under the sequential E:C method.
- Division of the work among several project constructors is readily accomplished.
- The engineer-manager's cost estimates are relied upon for project budget purposes, pending receipt of the last of possibly several constructors' bids, and the engineer-manager may be required to operate within that budget.

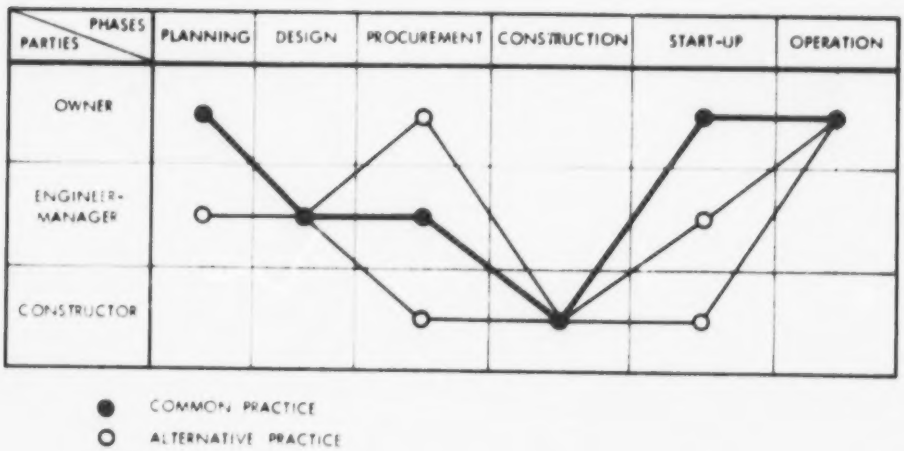

Figure 7-1. Typical Responsibilities of the Various Parties in an E&M Project

- When more than one constructor is involved, the engineer-manager functions in some of the roles of a general contractor, coordinating the work of several constructors and performing general job site administration.

- If prepurchase of long-lead-time items of equipment is necessary, the engineer-manager can serve as project purchasing agent for the owner and can expedite delivery and administer equipment warranties.

In the E&M form, the engineering firm acting as engineer-manager should have previous construction experience. Entities with limited construction capability should be expected to augment their organizations or form joint ventures with construction entities in order to participate in projects of this form.

7.2 CONTRACTOR SELECTION

7.2.1 Engineer-Manager

Under the E&M form of project execution, the basic roles of the engineer and the constructor remain the same as in the E:C form, except

that prospective engineers must have construction management experience in order to perform the manager's role. And in the public sector, a great deal of attention must be given in the selection of an engineer to the engineer's construction management experience.

In the public sector, the method of selection of the engineer-manager depends in part on whether the owner wishes to involve the selected contractor in the planning phase. At such an early stage, the magnitude of both the design and construction management functions is too indeterminate to allow firm cost or fee commitments by the contractor. At the completion of the planning phase, there is sufficient definition of process configuration, basic site specifications, and basic process criteria to allow a firm estimate of the engineering effort required to do the design phase of the project. At the same time, the engineer-manager is able to define with sufficient accuracy the scope and sequence of the procurement and construction effort needed to develop a formula for compensation of the management function.

In the private sector, the selection of the manager is done from qualification proposals or by direct negotiation with one or more candidates. The proposals may include unit cost data for various services and a description of the method of approach. Compensation terms are negotiated, and generally some form of reimbursable cost compensation is adopted for the early stages, with provision for renegotiating the compensation terms as the scope of work becomes better known.

7.2.2 Constructors

In the public sector, the constructors are selected as in the E:C form, namely, on a competitive price basis, using the engineer-manager's design report as the bid document. In the private sector, the constructor(s)

are usually selected by competitive price bidding. Prequalification of bidders may be used, but in any event, the owner and/or engineer-manager limit the length of the bidders list.

7.3 COMPENSATION

7.3.1 Engineer-Manager

The engineer-manager is compensated in two ways: 1) for his services as an engineer responsible for the preparation of drawings and specifitions, and 2) for his managerial role in overseeing total project performance, specifically the work of the constructor(s).

In the public sector, under the E&M form the methods of compensating the engineer are as in the E:C form. However, the amount of compensation paid to the engineer is proportionally more, consistent with his increased responsibility during the construction phase of the project.

In the private sector, a broader range of compensation methods may be used. But competitive lump-sum bidding for the total project cannot conveniently be applied because the scope of work is not well-defined when the engineer-manager is selected. If the engineer-manager is involved in the planning function, his engineering services are most apt to be compensated for on a reimbursable cost basis. If he is retained after the planning function, the definition of the work may permit the establishment of a lump-sum price for the engineering.

The compensation for the manager's role is normally on a reimbursable cost basis. But if the engineer-manager is expected to assume responsibility for the total project cost, in the form of a target price or GMP, his compensation will be included in that total amount and will be commensurately higher to reflect the greater financial risk. The opportunity for bonuses or target underrun shares increase the contractor's

probability of increased compensation and tends to offset his risk of penalties and overrun shares.

7.3.2 Constructor

The selection of the constructor is made after the completion of a firm engineering design. Successful lump-sum bidding establishes the basic compensation of the constructor, but in the private sector, other compensation forms may be used if desired by the owner.

7.4 RESPONSIBILITIES, GUARANTEES, AND LIABILITIES

7.4.1 Engineer-Manager

Under the E&M form, the engineer-manager's responsibilities for design are identical to those in the E:C form. As construction manager, the engineer-manager guarantees professional best efforts in the performance of the management task, including pursuit of supplier's and contractors' warranties, if necessary, on behalf of the owner. The engineer-manager gives the owner advice and consultation on construction costs and is responsible for providing the necessary services to keep project costs within budget estimates.

One of the principal advantages of management forms, including the E&M form, is that they can provide an efficient means of overlapping design and construction by breaking the project down into several procurement and construction units. As a result, there may be no single constructor to bid a firm price for the total project. Since the owner must rely solely on the engineer-manager's estimates for budget control, he may be called upon to assume some degree of responsibility for the overall project cost, in the form of a GMP or target price, and he may have to provide completion date guarantees and targets as well. The engineer-manager's financial liability under such cost and schedule guarantees is limited to some portion of the fee component of his compensation.

In the public sector, construction performance bonds are normally provided by the constructors to the owner through the engineer-manager. Likewise, equipment warranties are provided by the manufacturers to the owner through the constructor(s) and/or manager, who may be held responsible for pursuing them.

As in the E:C method, contractual process guarantees are not normally provided by the engineer, but because he is the manager with the greatest responsibility for the overall project, implicit process guarantees are expected of him.

7.4.2 Constructor

Under the E&M method, the constructors operate in the same manner, provide the same guarantees, and assume the same liabilities and responsibilities as in the E:C method.

7.5 LAW AND REGULATIONS

In the private sector, there are no laws or regulations bearing uniquely on the E&M form of project.

The federal, state, and local laws applicable to municipal wastewater projects are essentially the same for E&M as for E:C because of the basic similarity of forms. To perform some of the managerial services, the engineer-manager may need a construction contractor's license in some states.

The E&M form lends itself equally well to projects handled under EPA grant regulations, as either a traditional sequential engineering: construction or as a design & construct (Step Two/Three) procedure.

7.6 SUMMARY

The engineering and management (E&M) form of project execution can be described as an extension of the traditional E;C form, with more responsibility for project management being assigned to the engineer than would be traditionally given, or as a variation of the PM form wherein the manager does engineering work. It is similar to E;C in that all engineering and management functions are contracted for on a professional basis and provide for separation of financial interest from the constructor(s).

With the E&M form, the project period is easily expanded to include the planning, as well as design and construction. This feature strengthens the single-responsibility feature of E&M by providing greater technical continuity throughout the project.

Because no independent third party is available to represent the owner's interest concerning engineering, the E&M form is from the owner's viewpoint a weaker single-responsibility form than the PM form. Offsetting this drawback is the stronger position regarding process guarantees; this stronger position stems from the fact that the design engineer manages construction. Engineers practicing in the public sector may not have sufficient construction capability or financial resources to provide the level of project responsibility expected from the manager in the E&M form, but can enter into joint ventures, for example, in order to engage in this form of project.

The engineer-manager can provide earlier firm assurances of overall project cost than in the E;C form.

Guarantees and responsibilities assumed by the contractors under the E&M form are like those available under the E;C or PM forms, with stronger possibilities for process guarantees.

Laws, rules, and regulations do not prohibit the use of the E&M form. Under EPA regulations, it would appear that the method could be used to execute a project in a conventional manner or as a combined design & construct project.

When the E&M method is used as a means of overlapping design and construction, greater time savings can be achieved than in the sequential completion of design followed by construction, typical of the E:C form. And, as in the E:C form, design innovation and application of new technology are the responsibility of the engineer.

Section 8

CONSTRUCTION AND MANAGEMENT

8.1 GENERAL DESCRIPTION

The construction and management (C&M) project form is not used in the public sector. The practice of retaining the constructor by competitive price bidding precludes the possibility of contracting a construction firm to be both constructor and manager during the planning and design phases of the project. The additional duties that the constructor assumes are included in the discussion of the PM form in Section 6.

A typical division of responsibilities in a C&M project is illustrated in Figure 8-1.

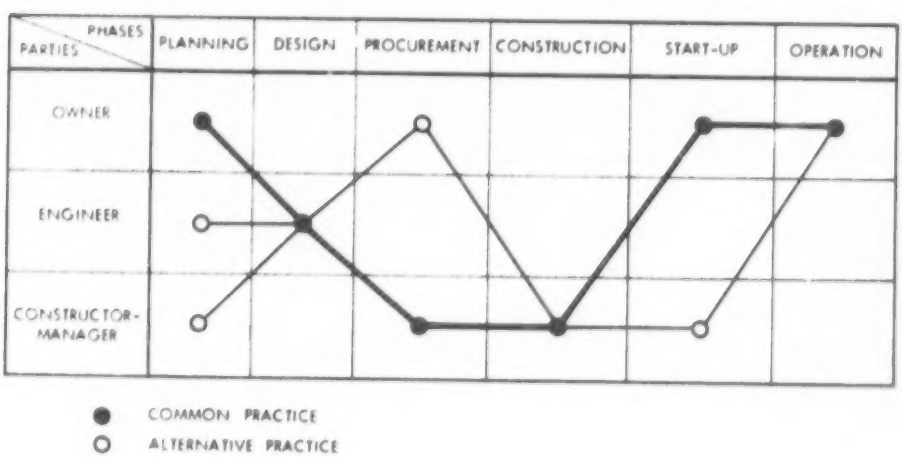

Figure 8-1. Typical Responsibilities of the Various Parties in a C&M Project

There have been a few major public projects in which the owner has contracted an engineering-construction firm for professional consultation in the formative stages of the project. But for the reason cited above, these projects did not result in any construction activities on the part of the engineering firm so retained, but evolved into what is more appropriately identified as the project management (PM) form.

Construction and management is a form used but rarely in the private sector. Normally, if an owner wishes to retain a constructor early in the project so that that firm can assume overall responsibility for the work, he selects an engineering-construction firm and enters into an EPC contract.

The primary application of the C&M form is in the special case where the owner retains a constructor with engineering capability to manage a design phase in which a proprietary or highly specialized process must be designed by an engineering firm holding patent or know-how rights to the process. The engineer may have limited overall engineering capability, or the owner may desire to limit the proprietary engineer's involvement. The constructor-manager will therefore coordinate 1) the proprietary design with other engineers, 2) the owner's effort, and/or 3) engineering done incidentally by the constructor himself.

This form has been included in this discussion because it is theoretically interesting. It permits the responsible contractor to offer stronger guarantees because of his direct involvement in the major share of the project in terms of value added. Widespread acceptance of this form in the public sector would require treating the constructor-manager as a professional and waiving the necessity of lump-sum competitive bidding as a means of selection.

8.2 CONTRACTOR SELECTION

Comments in this section pertain primarily to the private sector.

8.2.1 Engineer

The engineer may be selected by any of the means described in the discussion of other forms. The special case of applying proprietary processing units requiring specially qualified engineering firms has one function only – to establish a criterion for qualification of the candidates.

8.2.2 Constructor

Because the method of selection of a C&M form contractor must exclude lump-sum or other competitive price bidding based on a firm design basis, procedures of a more qualitative nature are used to retain the contractor prior to completion of the design phase. A few qualified contractors are preselected from candidates on the list to form a "short list," and combined compensation and qualifications proposals are requested. Compensation considerations must be limited to the contractor's management costs, exclusive of field material and labor costs, which are undefinable at that point. From this information, the owner selects the one or two most attractive bidders and negotiates a contract with one of them.

Appropriate engineering capability is a requirement in the selection of a manager.

8.3 COMPENSATION

A normal contract has provisions for starting the project on a reimbursable cost or unit price basis and includes an estimate of the number of man-hours expected during the early stages. On the other hand, if the owner has completed the planning phase and can conceptually describe the intended

facility adequately and if the proposing contractors have previous experience with that type of facility, they may initially agree upon firm compensation for the management services portion of the contract, to be followed by later negotiation of the construction portion. Provisions for a subsequent cost estimate determination and for negotiation of a firmer price are included in the contract terms. This stepwise firming-up of the compensation can bring the compensation to a lump-sum, target, or guaranteed maximum price, if desired.

The compensation method for the engineer under the C&M project form is the same as under other engineering only forms.

8.4 RESPONSIBILITIES, GUARANTEES, AND LIABILITIES

The constructor-manager's direct involvement in many aspects of the performance of the total project and the resulting magnitude of compensation suggest that of the several forms discussed in this report (except the EPC form) the C&M form offers the owner the greatest potential of obtaining significant financial support of guarantees from the contractor. An exception is the case involving the proprietary process design engineer in which process guarantees flow from that engineer to the owner directly.

In addition to process guarantees, the constructor-manager assumes the normal constructor obligations of material, workmanship, and performance guarantees. Also, in this form, certain professional performance obligations are required which pertain to the quality of his services and the obligation to pursue the warranties of others.

8.5 LAW AND REGULATIONS

In the private sector, there are no laws or regulations uniquely applicable to the C&M project form.

The C&M form may not be applicable in certain portions of the public sector because of legal restrictions. If, for example, an engineering-construction firm is retained on a professional consultant basis during the early phases of the project, that firm might be legally banned from consideration for the construction portion of the work. The firm could, of course, continue in the management role, in the manner of the project management (PM) form described in Section 6. As noted earlier, the almost universal requirement that public construction be procured on the basis of sealed competitive bids with award to the lowest responsive and responsible bidder makes it difficult, if not impossible, for this form to be used in the public sector.

A number of states require than an engineer or an engineering corporation must be licensed to perform engineering in both public sector and private sector projects. Whether the coordination and supervision of an engineer is considered "engineering" is subject to interpretation. The law in some states prohibits a corporation from practicing engineering, and this might reduce the C&M form's usefulness in those states.

8.6 SUMMARY

The construction and management (C&M) form of project execution is little used in either sector. It requires negotiated selection of a constructor at the start of the design phase. If bids based on performance specifications requiring engineering design effort are solicited, then the method is no longer C&M as described herein but EPC.

The C&M method is a relatively powerful single-responsibility method wherein engineering management and construction are in the hands of the party handling the major portion of the work – the constructor. For this reason, process (on a flow-through basis) and all other guarantees discussed for other forms can be expected of the constructor-manager.

Since most federal procurement regulations, many state and local laws, and present EPA regulations require competitive bidding for construction services in the public sector, C&M type projects in this sector are not possible.

Section 9

DISCUSSION

The foregoing sections have dealt with the manner in which design & construct projects are carried out. In the course of development of this material, certain ideas have suggested themselves. These ideas relate to the design and construction of wastewater treatment plants as partially funded under the EPA grant program. It is appropriate here to review such ideas in light of the EPA objectives for improved wastewater treatment plant projects as set forth in the Administrator's statement accompanying the issuance of the proposed revised regulations of 1971. These objectives are:

- To shorten project schedules
- To improve processing performance of treatment facilities
- To encourage the application of new technology

Implicit in the above is the desire to reduce costs or to increase cost-effectiveness of water pollution control expenditures.

A primary method suggested to achieve the EPA objectives is to increase the number of options available to the owner for obtaining single-responsibility project performance. The EPA can influence this through issuance of permissive regulations removing impediments to such options. There are, however, external factors such as local, state, and institutional requirements, beyond the direct reach of EPA regulations, that affect the owner's ability to exercise some of the options discussed in this report.

It has been noted that many private sector projects tend to be superior to public sector projects in terms of the three objectives noted above – presumably because of the different project organization methods used. What, then, are the characteristics pertinent to the stated objectives of the various available project forms?

9.1 SHORTER PROJECT SCHEDULES

From the public viewpoint, the chief value to be derived from shorter project schedules is the earlier implementation of treatment facilities. By mandate of its representatives in Congress, the public has less than four years to place in service a large number of water pollution control facilities involving at least secondary treatment. Major project periods, typically five years and longer, are not acceptable for achieving this goal.

Shorter project schedules mean reduced project time and increased cost savings. These savings result from shortened periods of construction management supervision, reduction of inflationary effects, and lowered probability of unforeseen impacts and changes.

If material availability, labor availability, and labor productivity are constant, there are basically two ways to shorten a project schedule: one is to eliminate any steps in the project procedure which advance neither design nor construction activities; the other is to overlap functions that were previously sequential. As will be seen shortly, some of the project forms discussed in the earlier sections lend themselves to one or both of these two methods.

The desire for shorter schedules has caused attention to be focused on the potential time savings resulting from overlap of normally sequential phases of design, procurement, and construction. In many private

sector projects, overlapping of this type is achieved by continuous release of design and procurement documents as they are completed. In the public sector, it is accomplished by a technique commonly called "fast-tracking." Fast-tracking is a stepwise increase of construction activity by means of multiple design reports (used as bid documents) and associated multiple construction bidding cycles, in lieu of a single design report and construction contract.

Figure 9-1 illustrates the relative differences in time to perform a hypothetical project by each of the three methods discussed here. In fast-track procedures, early design reports are completed for such initial construction activities as site preparation and foundations, while reports for mid-term and final job-site activities are prepared later. Fast-tracking permits an early start on the bidding and on the mobilization of constructors. The gains in project schedule and in leveling of the high-peaking field activity, however, are accompanied by an increase in the engineering and management effort required to prepare the additional bid documents and by an increase in the management effort required to handle the additional constructors (e.g., multiple constructors' bids must be received and evaluated for each portion of the work, and the numerous constructors working on the site must be coordinated).

Fast-track is suitable to the E/C, E&M, and PM forms. The faster continuous overlap is common in EPC projects, but can be practiced in any of the other forms if procurement rules allow it.

Whereas the fast-track method produces a stepwise progression, overlap of the project phases in the EPC and C&M forms is continuous. Thus, as each engineering document is completed, the constructor may proceed immediately with procurement and field work instead of awaiting

complete design reports. Continuous overlap saves more time than fast-tracking because:

- It requires less formal preparation of design data.
- It eliminates time for bidding cycles associated with design work released after selection of the original constructor.
- It eliminates the "learning curve" involved for each new constructor and avoids the coordination difficulties that arise when several general contractors are at the job site.

A disadvantage of continuous overlap is that it is not applicable to projects in which a lengthy design review is required by third parties (such as state and federal agencies) or where delays arise stemming from public disfavor. Because of the early commitment of resources, to attempt to operate on an accelerated basis in the face of such delays can be very costly and inefficient. Under such a design & construct procedure, construction may already be underway while plans are being reviewed and approved by the regulatory authorities. If requirements change, the question then becomes, "Who is now responsible for the project? – the owner (and his contractors) who submitted satisfactory performance specifications but "unsatisfactory" detailed plans; or the regulatory authority who approved the performance specifications, but will not approve the detailed plans or who is in some other manner delaying the project?

The EPC and the C&M forms eliminate the constructor selection period between the design and construction phases by shifting it to the outset of the project (except for subcontract work as discussed below). In itself, this shift tends to make EPC projects slower because the EPC contractor selection process is a relatively lengthy one. However, the time saved by continuous overlap of the schedule, including the construction

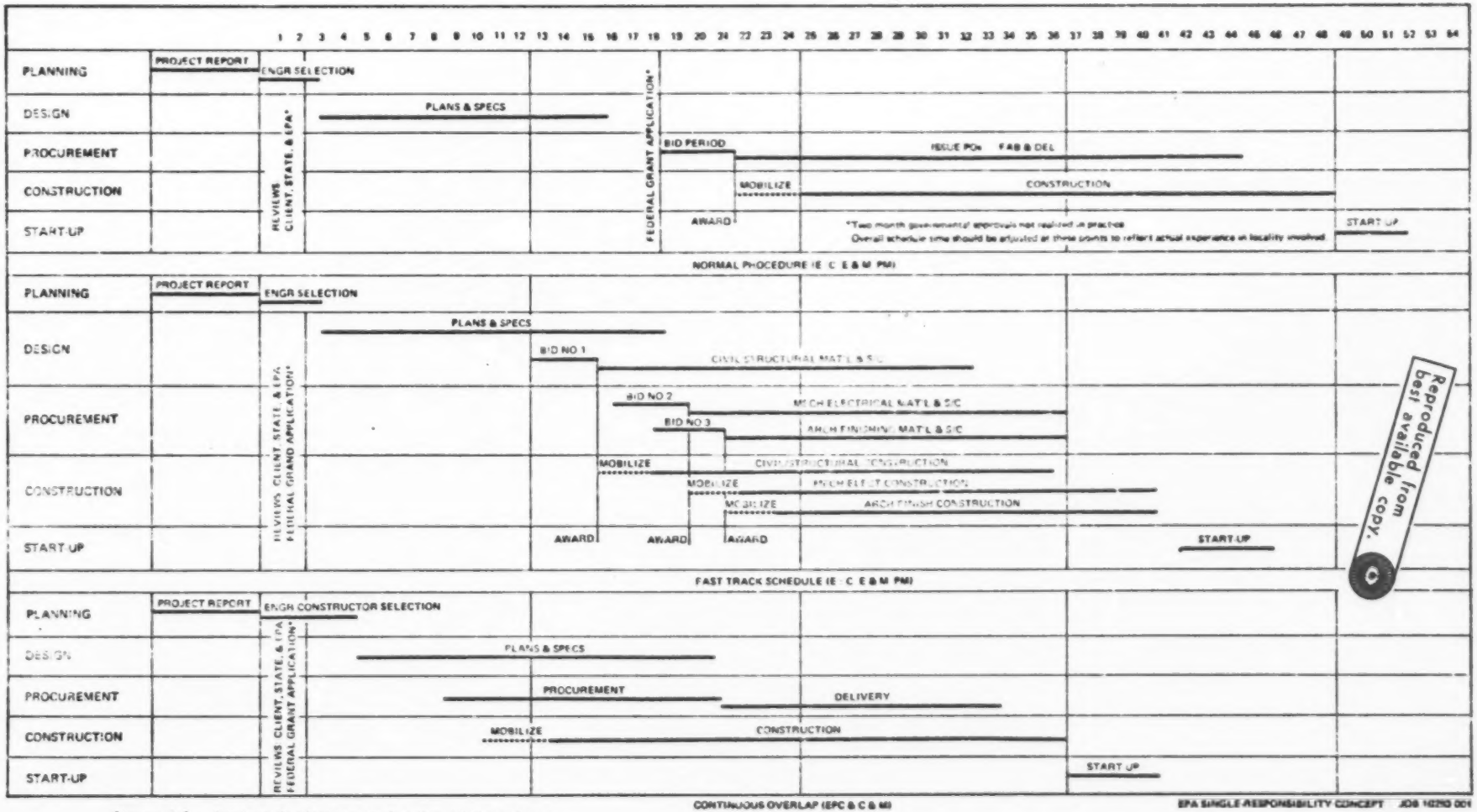

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Figure 9-1. Project Performance Using Normal Procedures, Fast-Track Schedules, and Continuous Overlap

subcontractor selection process, more than offsets the longer EPC contractor selection process. Subcontractors may be involved in from 25 percent to 100 percent of the field effort. The time involved for subcontractor selection is markedly reduced if private sector experience is followed and subcontractors are selected prior to completion of the detailed design through the solicitation of unit prices against preliminary drawings and quantity requirements. The result is a shorter bidding procedure and earlier award of subcontracts.

An example of the time savings available by schedule acceleration is a GSA study of a 10 million dollar building project estimated to require 60 months to complete by E:C methods, 48 months by PM methods, and 44 months by EPC methods.

A major time-consuming factor in public works projects is the need for design approval by both the owner (grantee) and the grantor agency, and also by numerous other external agencies and organizations. At present, the agency reviews that require detail design information coincide with the contractor bidding and selection period; hence the time effect is not readily apparent until project acceleration is attempted. The review requirements of state and federal agencies are outside the scope of control of the contract parties and limit the time-saving possibilities of applying either fast-track or continuous-overlap methods.

The latest EPA regulations concerning the use of design & construct methods by a Step Two/Three grant apparently allow a significant reduction in the amount of formality, the amount of detail, and the time frame in which the reviews are to be done by the EPA. If other reviewing agencies can be encouraged to reduce their review requirements in a similar way or if they can agree to work through a single review panel, the project acceleration characteristics of the design & construct forms can be realized.

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Many people involved in the design-construction industry question the need for extensive detailed review of drawings and specifications by public agencies. They point out that such materials have been prepared by qualified, licensed engineering contractors and reviewed by an owner who is experienced in the field and who may frequently have the assistance of outside consultants. It is suggested that public agencies concern themselves with assurances that the contractors are properly selected and that the owners are properly staffed, in lieu of providing the detailed technical surveillance now practiced. The one exception to this would be the review of major technical changes which may be proposed subsequent to the original approval.

Projects in the private sector include review periods by the owner — a recommended provision in any major capital project. These review periods are generally quite short (on the order of two weeks plus mailing time) and are frequently further shortened by stationing the owner's technical representatives in the design office of the contractor. If it is required that a technical review by grantor agencies continue as a matter of public policy, it is suggested that consideration be given to following the private sector example.

Another aspect of shortening project schedules involves the overlap of the procurement function with design and construction, specifically in prepurchase of materials. The concern for prepurchase of major equipment is well known, and prepurchase is practiced today in many E:C projects. It is generally limited, however, to those major items which are obviously of greatest importance to the schedule. But there are a number of materials, both specific and of bulk character, that can also be ordered early, thus helping to expedite field work. Any procedure, therefore, that selects the constructor before engineering work is complete, or that allows for the procurement of materials in advance of contractor selection, will improve project schedules. Such an accelerated

procurement mode can be used in any of the four single-responsibility project forms described in this report. However, the forms (such as EPC and C&M) that require early selection of a constructor permit pre-procurement of materials by the constructor himself and thus minimize difficulties in defining in advance the amount of material actually needed by the constructor.

9.2 IMPROVED PROCESS PERFORMANCE

It is in the area of satisfactory process performance that the subject of singleness of responsibility becomes a major issue. Process guarantees are often desirable, but not always possible. An alternative to tough process guarantees to obtain better process operation is to place the total project under the responsibility of a single agent capable of handling the process technology and the construction aspects of the overall project. All four project forms discussed herein were selected to satisfy this requirement.

Fundamentally, the responsibility for satisfactory project completion lies with the owner. He can select his agents and contractors carefully, assign certain responsibilities to them (with commensurate authority), require certain guarantees and assurances, and retain good advice, but he continues to be responsible to the public and the grantor agency. An example of owner involvement is his review and acceptance of cost-saving changes or technological improvements that are suggested by his engineer or that are implicit in his selecting an EPC contractor's bid and design.

Some of the factors affecting the degree of confidence in the process performance of treatment facilities are:

- The increasingly sophisticated chemical and biological processing nature of wastewater treatment plants,

which in turn increases the difficulty of the design engineers' task

- The reluctance of engineers (for reasons of professional custom or for lack of sufficient control of construction) to guarantee processes
- The wide variations in influent characteristics and flow, from the initiation to the completion of the project and during operating periods
- The difficulty of evaluating the actual performance of a facility relative to the anticipated performance, particularly when the facility is designed for future high-load conditions

It has been suggested that the complex question of greater assurance of good process performance can be easily solved through tough process guarantees. In practice, for a facility as complex as a wastewater treatment plant, this is too simplistic an answer.

If an evaluation formula is thoroughly prepared, if procedures covering expected ranges of influent characteristics and flows are used, and if the difficulties involved in the measurement of performance against design expectations are recognized, a moderately effective process evaluation can frequently be made. A form of process guarantee may be tied to this evaluation procedure. The primary effect of the guarantee, however, is to establish the process designer's intent to carry a moral responsibility for the performance of the completed facility. In addition, if financial liabilities are associated with the guarantee, they provide a commercial incentive to the designer to exercise care in the design and checkout of the processes involved. It must be recognized, however, that process guarantees represent a financial liability of the contractor, and that this liability is reflected in higher compensation requirements. There are basically two reasons why a process guarantee will not fully compensate the owner if the process does not perform: one is the limited liability the guarantor will accept; the other

is the high probability that conditions will change to an extent that will make it impossible to "prove" or "disprove" the guarantee.

Contrary to the commonly held view, the process designer, or the responsible party in a management type contract, cannot reasonably be held financially responsible for the total cost of revamping, or for the total replacement of a major process facility which has been constructed in accordance with his design. The actual financial responsibility assumed by the contractor must be contractually limited to a portion of his total compensation, which is a fraction of the total project cost. It can be expected that the total cash penalties for the failure of performance of the process will amount to perhaps three to seven percent of the total cost of the facility.

Two areas of apparent precedent for greater damage compensation deserve comment. The first involves small contracting firms which have accepted virtually unlimited liability, either in the process guarantees or in other contractual liabilities for damages. These cases are not germane to this report, however, because when a major claim is made against such an obligation, the seemingly significant liabilities, when distributed under the bankruptcy laws, are limited to some fraction of the net worth of the contractor. (An exception, of course, is any protection available through applicable bonds or insurance.)

The second area involves the practice whereby equipment suppliers offer a form of replacement guarantee. This is also not applicable to major process facilities because 1) manufacturers produce many of their product items, and 2) the "value added" component (i.e., the change in value from raw material to finished product) of their products is high. In contrast, the contractor's individual project is normally a major portion of his corporate worth at any given time and the "value added" component is relatively low.

It should be noted here that American equipment manufacturers are increasingly applying a common European practice in which certain process and equipment firms supply and guarantee complete process configurations incorporating their products. These configurations comprise both unit processes and complete treatment plants. "Packaged plant" or "systems design" offerings are frequently available as a special case of the EPC form. The guarantees commonly offered are more comprehensive than can be obtained from competitive engineer-constructors lacking a proprietary and profitable interest in the equipment they supply. Because these process configurations are as a rule completely different from competitive offerings and because there is little data available from nonproprietary sources, the owner and the manager who "passes through" to the owner these process configuration guarantees to the owner are dependent upon the supplier for data that substantiates the adequacy of the configurations.

Inherent in the various project forms discussed are certain tradeoffs between owner control and strength of guarantees. The project management approach can provide the highest degree of owner control and assurance of quality of the ongoing project, but with some sacrifice of direct responsibility. The EPC contract, on the other hand, may place a high degree of financial liability on the contractor while sacrificing some of the owner's control over the manner in which the project is carried out. The choice of a project form, therefore, involves a certain tradeoff between the owner's desire to maintain close control of the project while it is in progress, and the advantage of a high, if somewhat limited, financial obligation against the contractor. It is generally acknowledged that a well-controlled project is more satisfactory for all parties concerned than a loosely controlled contract in which the owner depends upon potential financial claims against the contractor as a means of bringing about a quality effort.

This report has emphasized the desirability of placing central responsibility for overall project performance on a single contractor selected by the owner in any one of the several project forms described. A most important contribution to the centralizing of responsibility is the involvement of the contractor in the planning phase. This assures technical continuity through all phases of the project.

The reluctance of the owner to bring in an additional party (such as the manager) at a very early stage in the development of the project can be expected. This reluctance stems from general inertia and a disinclination to assume the burden of the extra costs involved. But if the owner is to be held responsible in an overall way for the success of the project, including the processes, he must take part in the process selection or be provided an opportunity to accept – perhaps with modifications – the processes that are adopted. Postponing this selection may result in inefficient use of engineering time and may cause delays in the project schedule in addition to dividing responsibility and weakening guarantees. It is recommended, then, that for all forms (including EPC, if negotiated selection is allowed) the responsible contractor should be selected in the planning phase of the project. Similarly, in the requests for bids, EPC contractors should be asked to acknowledge acceptance of specified process configurations and to give notice of any modifications they would expect to incorporate before assuming a process guarantee obligation.

The ability to predetermine discharge requirements and influent wastewater characteristics can be an important factor relating to the applicability of design & construct forms. In recent years, the quality standards and consequent discharge requirements have changed rapidly, frequently, and without warning. All too often projects have had their basic design criteria or procedures changed between initiation and completion. It is felt, however, that this situation should be expected to improve as a result of the adoption of the 1972 Act and that, with approval

of basin-wide and metropolitan plans, there will develop greater stability in the application of discharge requirements (subject to settlement of the meaning of "best practicable treatment" and so-called "zero discharge").

The viability and utility of design & construct procedures, relative to process guarantees and centralized responsibility, depend upon the ability of the owner and his contractor to establish process and performance criteria and to be free to proceed with the project without change by some higher authority.

9.3 NEW TECHNOLOGY

The third consideration of the EPA in attempting to broaden the range of alternative methods of wastewater treatment plant construction involves the encouragement of the application of new technology.

The subject of new technology can be divided into two categories. The first pertains to inventions of new processing methods and improvements which develop through invention of equipment or reconfiguration of processes. (This reference to invention is not intended to imply that an objective of the EPA construction grant program is to encourage invention originating from basic and applied research.)

Inventions normally need to be tested by means of pilot plant or prototype operation to establish confidence in their soundness and to develop the appropriate scale-up factors needed for adaptation to operations of commercial size. Basic inventions or major process improvements require a period of testing under various operating and influent quality conditions before they can be incorporated in new construction with any degree of confidence; hence these inventions and process improvements cannot be used within the design & construct project period.

Process and equipment suppliers contribute technological advancement by offering proprietary processes invented and developed at their own expense, and these expenses must be recovered through compensation when these processes are used in a facility. Otherwise, the fast-moving design & construct project tends to discourage the application of new inventions, because inherent in such a project is a tighter guarantee position which strongly discourages the contractor from using new, untried innovations.

The second category of technological innovation is that which may result from a value-engineering type of activity. It is associated primarily with the improvements that can be made in terms of plant operating quality or cost as developed by enterprising engineers during the planning or design phases. Such innovations are sometimes referred to as "paper improvements" because they appear in the specifications or in the drawings prepared by the engineers. Generally, with old and well-established processes, improvements made by this means are relatively minor. Occasionally some major change can result through the use of new materials of construction or through some new form of mechanical equipment or equipment design. These innovations have frequently been drawn from other experiences of the engineer and are not necessarily related to the specific application under question.

Paper improvements normally appear in the form of capital-cost reductions, as this is the normal basis for evaluation of proposals. If, however, the invitation to bid includes other quantifiable evaluation criteria - such as estimate operation and maintenance costs in the life cycle of the plant, or quantitative credits for incremental improvements in processing quality - some technological improvement will be stimulated.

Paper improvements can be encouraged by the design & construct projects in several ways. Through the EPC form, for example, the

owner is exposed to the ideas of various bidders. The latter work from basic criteria and attempt to design to the lowest first cost (or lowest facility life-cycle cost) by looking for the maximum number of paper improvements to better their competitive position. This has been moderately effective in the private sector. Transfer to the public sector, however, might be inhibited by the fact that the bidder's ideas are always made public (even if his bid is unsuccessful), thereby injuring his future competitive position.

Some innovation could be encouraged by expanding the usual design & construct contract to include a portion of the process planning phase. The contract could provide a time period for development work on alternative processing schemes. The scheme that appears to offer the greatest promise at the end of that period would be selected, and its pilot plant testing completed prior to formulation of the process design criteria upon which the final design would be based. Because it establishes a specified time and level of effort for the required activities, this scheme could be defined in terms suitable for relatively fixed-price bidding or negotiation. There would have to be an agreement that the design would proceed on the basis of the results of the development accomplished in the time available. With this approach, the time period and level of effort required may rule out any major technological breakthrough and may make it impossible for the contractor to guarantee the extent of technological improvement possible. If one or more methods were actually tested, however, a significantly better processing scheme which used existing technology could be expected for a given influent characteristic than normally would be the case, with or without paper improvements. In this approach, the designer's guarantees would be established after completion of the test work by use of some previously agreed-upon formula.

Similarly, preliminary estimates of the probable cost of the facility are subject to modification following the process definition, although the

original estimate could be set as the goal or ceiling cost for the final process facility design. Major process improvements that might increase the capital cost could be dealt with in the context of the owner's desire and ability to supply the incremental capital needed for the implementation of these improvements.

Another method of encouraging paper improvements would be for the grantors to include in the evaluation of grant applications some priority credits for designs that incorporate technological innovation. But this can be a very difficult thing to evaluate. Similarly, the grant application could include indications of how the contractors are to be selected and the extent of encouragement of technological improvement expected from the bidders.

In summary, the introduction of design & construct project methods in itself is not a major impetus (if it is any impetus at all) to the improvement or advancement of the technology of the wastewater treatment industry. The most direct and effective method of encouraging invention, demonstration, and application of new process technology is through research or demonstration grants.

9.4 PROJECT OPTIONS

As regards optional project methods, the application of the individual forms will have a differing impact on achievement of the EPA objectives. In this report, very clear lines of demarcation have been drawn between the various project forms, based upon the contractual relationship between the owner and the contractors and upon any existing third-party agency agreements that influence these contractual relationships. In practice, of course, the actual form in which projects are performed will sometimes vary markedly from the standardized forms illustrated. There can also be considerable overlap in the actual performance of

projects among forms that are categorized differently. The project sphere in Figure 2-1 illustrates the way in which project relationships flow into one another. As project forms are followed through their variations, the characteristics of the project in terms of degree and centrality of control, extent of guarantees, and seat of responsibility will also vary. The actual form selected for any given project, then, is the one which best represents the interests of the owner and which takes into consideration his previous experience, his in-house capability, the experience of potential contractors available, and the contraints of laws and regulations.

An example of how two seemingly different project forms (appearing on opposite sides of the sphere in Figure 2-1) can be quite similar involves the PM and EPC forms. The PM form can be operated quite like the EPC form; the owner can grant broad agency powers to the manager to contract (on behalf of the owner, of course) all engineering and construction functions, just like an EPC contractor operating on a total subcontract basis. When a high degree of responsibility is given to the project manager, he could be expected to supply performance, material, workmanship, and process guarantees similar to, if not quite exactly as extensive as, those that would be expected of the EPC contractor.

In the private sector, the two forms when performed as described above might be outwardly almost indistinguishable. In the public sector, however, the applicable procurement rules, as now constituted, would usually prevent the forms from being operated in so similar a manner. The project manager would be selected as a professional consultant, free of the competitive bidding currently required for the retention of an EPC contractor. On the other hand, once an EPC contractor is selected, he is free to retain subcontractors within his own procurement rules, whereas the project manager is restrained to the competitive lump-sum bidding procedures presently required in public procurement for construction. The

effect of the public procurement rules on schedule would be to slow the job for the project manager as he went through the more formal bidding procedures for the individual (sub)contractors. This fact accounts for the four months' difference between EPC and PM projects as observed by the GSA study referred to earlier in this section.

Owner capability is a significant factor when choosing a project form. Required technical and managerial competence and capability are directly related to the size and complexity of projects. An owner with a large and sophisticated staff may have the technical and management competence in-house to handle any wastewater project. This capability, however, may already be overtaxed by an unusually heavy load of other projects underway. Smaller public agencies are even less likely to have in-house either the quality or quantity of skills required. This is no doubt the case for most grant applicants. Unfortunately, this situation is not clearly perceived by many public entities. Engineers and constructors working in the public arena are all too frequently acquainted with the fact that their clients underestimate both the quantity of work involved and the skill required to successfully handle wastewater management projects. They tend to be reluctant, therefore, to release to their contractors the degree of authority required to carry out design & construct projects as considered in this report.

The owner's capability must be considered from the standpoint of the need for technical review (e.g., the review of EPC contractors' bids) and for monitoring the performance of the contractor if guarantees or other significant obligations of the contractor suggest an adversary relationship may develop.

The individual project forms may be categorized in terms of the owner's technical and managerial strength requirements, as shown in Table 9-1.

Table 9-1

COMPARISON OF PROJECT FORMS

Form	Owner's required technical and managerial strength
E:C	Moderate
EPC	High
PM	Low
E&M	Low
C&M	Low
PM:EPC	Minimal

If strong guarantees are expected of the contractor, a stronger owner organization is required than that shown in Table 9-1. In such cases, it may be desirable to increase in-house capability by retaining a consultant.

The type of project form to be selected for any given project, as we have observed, is based on a number of factors. These are: the size of the project; its complexity; the degree of sophistication of the owner agency (including the extent of previous experiences of the owner in similar types of projects and his technical capability); the availability of competent single-responsibility contractors for the form selected; the extent of guarantees or other obligations of the contractor; and perhaps most critical, the applicable procurement rules or laws which might constrain the method of performance of the project or form selected, or more important, the method of compensation.

The potential for transfer of private sector experience to the public sector depends on several factors. The fundamental points of differentiating the public sector project from its counterpart in the private sector are:

- The absence of the profit motive on the part of the owner.
- The stewardship responsibility of public officials dealing with public funds
- The need in public agency procedures for full public disclosure of business matters and decision variables
- The relative absence of constructor preselection
- The legal and regulatory obligation to select the lowest responsible bidder for construction work
- The limited technical capability of owners
- The uniqueness or infrequency of occurrence of major projects during the tenure of public officials

Very small projects, lending themselves to skid-mounted or simple field-erected single-stage process package units, are probably best procured like major equipment, as is commonly done in the industry today in what is essentially an EPC project form. Other small jobs can be E&M or EPC, where allowed.

Intermediate-size projects can be carried out in any form. But the provision of adequate full project capability in very large projects may be beyond the capacity of many individual engineers and constructors, in which case the PM and PM:EPC forms appear preferable. Alternatively, the E & M form can be carried out by large engineering-construction firms, or by joint ventures of engineers and construction contractors, to gain the construction expertise not commonly available in engineering only firms.

It may be concluded that:

- There are a number of options that can be used in the performance of wastewater treatment facility projects.
- The various forms may be individually feasible, to a greater or lesser extent, depending upon the external conditions that exist for each separate project situation.

- A reevaluation of contractor selection methods as presently practiced is necessary. Increased consideration of cost in selection of engineers and managers is expected. De-emphasis of strictly fixed price methods of selecting constructors and increased use of negotiation based on relative qualifications will be needed to implement some of the project performance options discussed herein.
- The consideration of these optional forms can be encouraged by revising EPA regulations that now forbid them.
- The best form in any project is probably that which encourages the selection of the most qualified group of contractors.

Appendix A

GLOSSARY OF TERMS

Accelerated Schedule is the shortening of a project schedule through overlap of the construction and engineering phases by fast-track or continuous means.

Completion Date Guarantee is a guarantee by the contractor to complete his work within the time limits specified in the contract.

Compensation is the price paid (i.e. the money contracted to be paid) by the owner to the contractor for the supply of materials and the performance of services. Compensation normally covers the contractor's profit, direct costs, indirect costs, fee, and incentives (bonuses or penalties). It may be as reimbursement of costs by a formula that takes these factors into account in the form of unit rate payments in lieu of direct reimbursement or lump-sum payments.

Construction is a function of the constructor and involves the performance of the site preparation work, the building of structures, the procurement of specified materials, and the assembling, erecting, and installing of the various material components delivered to the site. The construction activities include materials receiving and warehousing, job site security, labor relations, labor supervision, services subcontracting, job site procurement, cost control, progress control, and quality control. The term "construction phase" also includes the on-site inspection function by other parties, such as the engineer or manager, for assurance of quality of workmanship and conformance to design.

Constructor is the party (individual, partnership, or corporation) that performs construction services and procures the required materials.

Continuous Overlap is the means of schedule shortening in which procurement and construction is released to proceed as each engineering document is completed.

Contractor is any party entering into a contract with the owner, whether it be for engineering, construction, management, or other services.

Cost is the actual expense incurred by a party to the contract. Contractor's compensation by the owner is an owner's cost, but the word "cost" as used here is in general reserved for the expenses (e.g., salaries, materials, services, license fees, taxes, etc.) that the contractor incurs in performing his services

Cost-Plus Fixed Fee (CPFF) is a form of compensation whereby specified contractor costs are reimbursed and the fee is established in the original agreement as a fixed sum of money.

Cost-Plus Percentage Fee (CPPF) is a form of compensation whereby contractor costs are reimbursed and a fee is established as a fixed percentage, either of those costs or of the facility.

Design is the engineering function which includes detailed calculations, drawings, specifications, and materials and subcontract requisitions. Non-engineering activities, such as cost budget preparation and project schedule preparation, are also considered to be part of the design phase.

Design & Construct refers to a type of project in which a single responsible entity is in charge of or oversees both the design and the construction (and perhaps planning and/or start-up) activities that are performed.

Direct Costs are those directly attributable to activities of a specific project, including salaries and wages, fringe benefits, and payroll taxes, costs of supplies, materials, equipment, freight, insurance, various fees, etc.

Engineer is the party (an individual, partnership, or corporation) that performs engineering in connection with a project. For purposes of this study, the term "engineer" is applied specifically to the party that performs professional services associated with the design phase.

Fast-Track is a stepwise type of schedule acceleration involving the preparation of multiple-design reports for construction bidding.

Fee is that additional sum of money, over direct and indirect costs, included in the compensation of the contractor to provide him a reasonable profit based on the extent of his services and on the financial risks undertaken. The word "fee" as used here should not be confused with total compensation, with reimbursement for direct salaries and other costs, or with indirect job-related costs.

Fixed Price is fixed compensation of a contractor for an agreed-upon amount of work.

Guarantee is a promise given by the contractor to the owner concerning the fact and/or quality of his performance of his contractual obligations. A guarantee is normally supported by an obligation of the contractor to do something or pay some specified amount (to some limit) if he fails.

Guaranteed Maximum Price (GMP) is a fixed value of compensation which sets an upper limit for reimbursable costs. Material and services costs that exceed the GMP must be swallowed by the contractor.

Incentives are the adjustment of the contractor's compensation to reward promptness of completion and/or quality of the work. Liquidated or other damage payments made by either party are not considered compensation or incentives in this sense.

Indirect Costs, also called overhead, burden, markup, multiplier, and similar names, are those costs, incurred by an entity, that are assigned to a specific project by proration and are attributable to general administrative and operating expenses common to all projects being carried on at one time by the entity. Included are expenses such as office space, heat, light, furnishings, etc.; and executive and administrative employees' salaries and associated expenses (including the cost of maintaining central service offices, such as legal, procurement, general accounting, etc.). Indirect cost is a matter of definition in the contract between the owner and contractor, but contractors attempt to have it defined in the same way in all of their contracts to assure that the common pool of indirect costs is equitably distributed to all projects.

Lump-Sum Price is that fixed compensation which a contractor commits to the performance of a specified amount of work.

Management is the commercial and technical surveillance of a project and the parties performing it for the purpose of assuring satisfactory performance and completion of the activities. This function can be performed by the owner or by a party contracted by the owner (by means of an agency-type contract) to act on his behalf with regard to third parties used in the project.

Manager is the party (an individual, partnership, or corporation) that performs management as defined herein.

Materials and Workmanship Guarantee is a guarantee by the contractor to provide materials and workmanship of a nature and quality as specified and agreed to in the contract or, in the absence of specified and agreed-to standards, in conformance with standards commonly acceptable in general usage.

Owner, as used in this study, is the party, public or private, for whom the project is executed. The owner is the party who will have ownership title to the completed facilities.

Parties are those entities contracted to engage in the performance of the project. The parties are the owner, the planner (optional), the engineer, the constructor, and the manager (optional).

Percentage (of Facility Cost) Compensation is an amount of compensation determined as an agreed-upon fraction of the cost of the facility being provided in the project. Either an early estimate of the cost or the actual completed cost of the facility may be used. The components of the facility cost are subject to contract definition. They usually include the contractor's cost for technical services, materials, and labor, but do not include owner's costs.

Performance Guarantee is a guarantee by the contractor that he will perform all work and services specified in the contract.

A Phase is a chronological segment or major sequential step of a project. It is normally capable of standing alone for scope definition purposes. Phases include planning, design, construction, and start-up.

Planning is the activity, preceding the design, wherein the planner establishes the feasibility of the basic criteria, screens alternatives and recommends the preferred configurations of the intended facility, or

develops financing plans. These activities vary widely in magnitude, depending upon the complexity of the problem and the availability of time and money for such work. The planning activities may also include testing by means of laboratory, pilot plant, or semi-works facilities; site selection; economic analysis; sewer system analysis; infiltration/inflow studies; and environmental assessment. Typical final planning documentation includes site data, economic and financial data, process flow diagrams, material balances, physical property data for process fluids and solids, rating data for equipment, and basic control system requirements.

Process Guarantee is a guarantee by a contractor that the completed facility will perform in accordance with agreed-upon criteria.

Procurement is a function involving purchase of materials (including the qualification of suppliers and the solicitation of bids), expediting of suppliers, and factory inspection, where desired. This function is not a separate phase, but is performed in conjunction with the design and/or construction phases. The review of the suppliers' drawings is done in conjunction with procurement, but this is an engineering function which may be performed by either the engineer or the constructor, depending upon the method of project execution.

Public Sector, as contrasted to Private Sector, generally refers to owners who are governmental agencies, at any level, including regional administrations operated by non-elective officials or public corporations operating under governmental procurement regulations. The primary differences between public sector projects and private sector projects are that in the former, public disclosure of contractual action is required and the profit motive is absent.

Reimbursable Costs are those costs agreed upon by contract to be passed on to the owner by the contractor. Any contractor's cost not subject to reimbursement is a nonreimbursable cost.

Single Responsibility refers to the use of a single party under contractual obligation to the owner to perform or be responsible for a specified amount of work and/or services required to carry out a design & construct project, whether or not there are financial penalties for failure to perform.

Start-Up is the activity whereby the completed facility is put into operation to perform the function for which it was designed. This includes starting and adjusting the equipment, installing in-process inventory, writing of O&M and operator training manuals, and (if necessary) performing test runs to see whether process performance requirements are met.

Target Price (TP) is a mutually agreed-upon value of compensation around which the contractor and the owner share in overruns and underruns according to a specified formula.

Unit Price is a compensation form in which measurable units (such as man-hours for professional services of labor) or quantities of materials supplied by constructors are assigned a value by contract. Compensation is calculated by multiplying the number of units with the unit price.